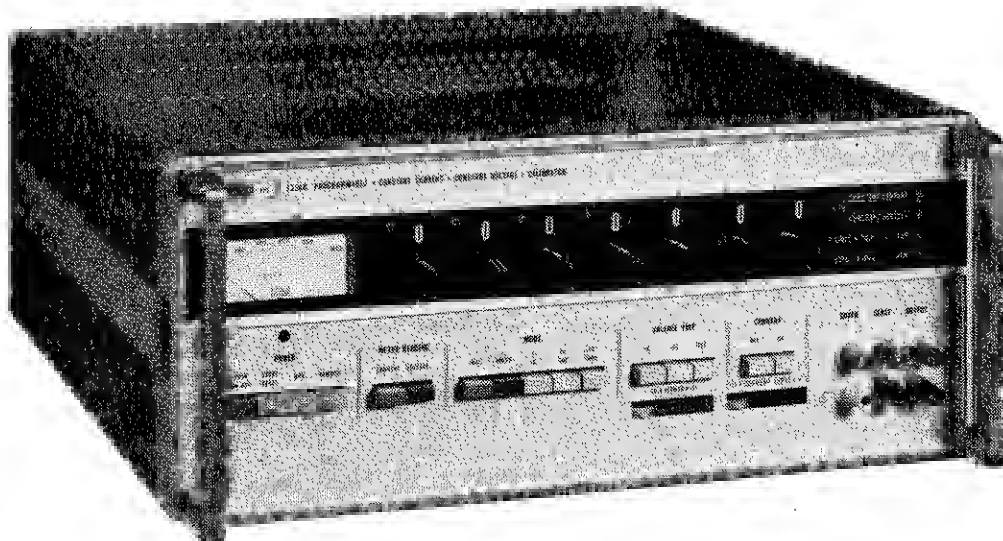


# JOHN FLUKE MFG. CO., INC.

P.O. Box 43210

Mountlake Terrace, Washington 98043



## 3330B

PROGRAMMABLE CONSTANT VOLTAGE/  
CONSTANT CURRENT CALIBRATOR

Rev. 1 11/72

Rev. 2 4/75

# WARRANTY

The JOHN FLUKE MFG. CO., INC.\* warrants each instrument manufactured by them to be free from defects in material and workmanship. Their obligation under this Warranty is limited to servicing or adjusting an instrument returned to the factory for that purpose, and to making good at the factory any part or parts thereof; except tubes, fuses, choppers and batteries, which shall, within one year after making delivery to the original purchaser, be returned by the original purchaser with transportation charges prepaid, and which upon their examination shall disclose to their satisfaction to have been thus defective. If the fault has been caused by misuse or abnormal conditions of operations, repairs will be billed at a nominal cost. In this case, an estimate will be submitted before work is started, if requested.

If any fault develops, the following steps should be taken:

1. Notify the John Fluke Mfg. Co., Inc.\* giving full details of the difficulty, and include the Model number, type number, and serial number. On receipt of this information, service data or shipping instructions will be forwarded to you.
2. On receipt of the shipping instructions, forward the instrument prepaid, and repairs will be made at the factory. If requested, an estimate will be made before the work begins, provided the instrument is not covered by the Warranty.

"The foregoing warranty is in lieu of all other warranties, express or implied, including but not limited to, any implied warranty of merchantability, fitness or adequacy for any particular purpose or use. Fluke shall not be liable for any special, incident or consequential damages."

## SHIPPING

All shipments of John Fluke Mfg. Co., Inc.\* instruments should be made via United Parcel Service or "Best Way"\*\*\* prepaid. The instrument should be shipped in the original packing carton; or if it is not available, use any suitable container that is rigid. If a substitute container is used, the instrument should be wrapped in paper and surrounded with at least four inches of excelsior or similar shock-absorbing material.

## CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be thoroughly inspected immediately upon receipt. All material in the container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to John Fluke Mfg. Co., Inc.\* Upon receipt of this report, you will be advised of the disposition of the equipment for repair or replacement. Include the model number, type number, and serial number when referring to this instrument for any reason.

The John Fluke Mfg. Co., Inc.\* will be happy to answer all application questions which will enhance your use of this instrument. Please address your requests to: JOHN FLUKE MFG. CO., INC., P.O. Box 43210, MOUNTLAKE TERRACE, WASHINGTON 98043\*.

\* For European customers: FLUKE (Nederland) B.V.  
Ledeboerstraat 27  
Tilburg, Netherlands

\*\* For European customers, Air Freight prepaid.

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# Introduction & Specifications

## 1-1. INTRODUCTION

1-2. The Model 3330B Programmable Constant Current-Constant Voltage Calibrator is a dc calibration instrument which produces output currents from 0 to 111.11110 milliamperes and output voltages from 0 to 1111.1110 volts dc. Output current selection is provided in three ranges and is accurate to within 0.006% of the selected range. Output voltage selection is also available in three ranges with accuracies as stated in paragraph 1-6. Over current and voltage protection features are also provided, thus preventing harm from occurring to devices being tested with this instrument.

1-3. Front panel indicators provide visual indication of the output current or voltage and the operating modes of the instrument. In-line decade dials and a panel meter indicate the magnitude of the selected output. Indicator lamps provide visual indication of the various operating modes.

1-4. Systems capability is enhanced by remote control of most operating features. Remote operation is possible through the rear panel Remote connector using either contact closures or DTL/TTL logic. Programming coding requirements are binary 8-4-2-1.

1-5. The instrument is completely solid-state in design, and module plug-in construction is used for ease in maintenance. The instrument is designed for bench-top use or installation in a 19-inch electronic equipment rack. The chassis is also drilled to accept rack mounting slides.

## 1-6. SPECIFICATIONS

### 1-7. Constant Voltage Mode

#### ANALOG OUTPUTS

10V Range - 0 to 11.111110 volts dc (1 uv steps)

100V Range - 0 to 111.11110 volts dc (10 uv steps)

1000V Range - 0 to 1111.1110 volts dc (100 uv steps)

#### ACCURACY OF OUTPUT:

(% of Programmed Level)

10V range -  $\pm 0.003\%$  or  $\pm 30$  uv

100V range -  $\pm 0.003\%$  or  $\pm 300$  uv

1000V range -  $\pm 0.003\%$  or  $\pm 3$  mv

*NOTE: Above accuracies apply for 90 days at standard reference conditions of  $23^{\circ}\text{C} \pm 1^{\circ}\text{C}$  (nominal calibration temperature, constant line voltage, up to 70% relative humidity, and constant external load.) With uninterrupted operation for more than one hour at loads greater than 25 mA, the specified accuracy is  $\pm 0.005\%$  over an operating temperature range of  $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$ .*

#### OUTPUT CURRENT:

10V and 100V Ranges - 0 to 100 milliamperes at any programmed level.

1000V Range - 0 to 50 milliamperes at any programmed level.

#### TEMPERATURE COEFFICIENT OF OUTPUT:

Less than 4 ppm of programmed level or 0.4 ppm of range/ $^{\circ}\text{C}$ .

## STABILITY OF OUTPUT:

10V Range - 5 ppm of output or 10 uv/day  
 15 ppm of output or 30 uv/month

100V Range - 5 ppm of output or 100 uv/day  
 15 ppm of output or 300 uv/month

1000V Range - 5 ppm of output or 1 mv/day  
 15 ppm of output or 3 mv/month

*NOTE*

*Stabilities apply at standard conditions described under accuracy of output.*

## RIPPLE AND NOISE:

	UP TO 50 MA LOAD	UP TO 100 MA LOAD
10V Range	60 uv rms	100 uv rms
100V Range	70 uv	100 uv
1000V Range	100 uv	Not applicable

## LINE/LOAD REGULATION:

5 ppm of programmed level or 2 ppm of range for combined 10% line voltage and full-load changes.

**1-8. Constant Current Mode**

## ANALOG OUTPUTS:

1 MA Range - 0 to 1.111110 ma (0.1 na steps)  
 10 MA Range - 0 to 11.111110 ma (1 na steps)  
 100MA Range - 0 to 111.11110 ma (10 na steps)

## ACCURACY OF OUTPUT:

$\pm 0.006\%$  of programmed level, or  $\pm 0.0006\%$  of current range.

*NOTE*

*Accuracy applies for 90 days at standard reference conditions described under constant voltage mode.*

## TEMPERATURE COEFFICIENT OF OUTPUT:

Less than 6 ppm of programmed level or .4 ppm of range/ $^{\circ}\text{C}$ .

## STABILITY OF OUTPUT:

10 ppm of programmed level or 1 ppm of range/day.  
 30 ppm of programmed level or 6 ppm of range/month.

*NOTE*

Stabilities apply at standard conditions described under constant voltage mode.

## COMPLIANCE VOLTAGE:

1 ma and 10 ma Ranges - up to 1000V  
 100 ma Range - up to 500V  
 (See voltage limit)

## RIPPLE AND NOISE:

For negative ground or floating operation.

MA RANGE	RIPPLE
1 MA	20 na
10 MA	100 na
100 MA	1 ua

## LOAD REGULATION:

1 MA Range - 2 ppm of range per 100V compliance  
 10 MA Range - 5 ppm of range  
 100 MA Range - 5 ppm of range

**1-9. General Specifications**

## CURRENT LIMIT (voltage or current operation):

Remote mode - Programmable in 12 steps from 1.0 to 110 ma. (see input/output table)  
 Local mode - Continuously adjustable from 1 ma to 110 ma.

*NOTE*

*Limit indication by contact closure (see input/output table), and front panel lamp.*

## VOLTAGE TRIP (voltage or current operation):

Remote mode - Programmable in 10% steps from 10% to 110% of trip range (see input/output table)

Local mode - Can be calibrated to be continuously adjustable from 10% to 110% of range (see Voltage Trip-calibration procedure).

# NOTE

*In the constant current mode, the actual absolute trip voltage is decreased by the following:*

$$10 \times \frac{\text{Output Current}}{\text{Output Current Range}} \text{ Volts}$$

# NOTE

*Output goes to zero and unit returns to standby if trip point is exceeded. Limit indication by contact closure (see Table 1-1) and front panel lamp.*

# ISOLATION:

Programming lines are isolated from output. Output is isolated and guarded from chassis. Potential between programming lines and either side of output should not exceed 1150V.

# METER:

For local operation, switch selectabel to indicate 0 to 1100 VDC or 0 to 110 ma.

# PROGRAMMING INPUTS/OUTPUTS:

All inputs/outputs through a 50 pin rear panel connector. Mating connector furnished with instrument. See Table 1-1 for line functions.

# OUTPUT CONNECTIONS:

Separate output and sense terminals provided for four-terminal connection to the load. All front

Table 1-1. PROGRAMMING INPUTS AND OUTPUTS

INPUTS	LINES	CODING	INPUTS	LINES	CODING
		Logic "0" = +4.5 to +20V or open circuit Logic "1" = 0 to +0.5V or closed circuit			40 = 0100 50 = 0101 60 = 0110 70 = 0111 80 = 1000 90 = 1001 100 = 1010 110 = 1011
STANDBY OPERATE	1	STANDBY = "0" OPERATE = "1"			
MOOE	1	VOLTAGE = "0" CURRENT = "1"	VOLTAGE TRIP:		
RANGE	2	CODE "00" (Code "11" not allowed) "01" "10"	VOLTAGE TRIP RANGE	2	CODE 00 01 (Code "11" Not Allowed) 10
10V or 1 MA			10V TRIP RANGE		
100V or 10 MA			100V TRIP RANGE		
1000V or 100MA			1000V TRIP RANGE		
OUTPUT LEVEL (7 Decades)	28	DECADE CODING DIGIT 8421 0 = 0000 1 = 0001 2 = 0010 3 = 0011 4 = 0100 5 = 0101 6 = 0110 7 = 0111 8 = 1000 9 = 1001 10 = 1010	REMOTE TRIP LEVEL (10% to 110% of selected range)	4	CODING RANGE % 8421 ≤1% = 0000 10% = 0001 20% = 0010 30% = 0011 40% = 0100 50% = 0101 60% = 0110 70% = 0111 80% = 1000 90% = 1001 100% = 1010 110% = 1011
VOLTAGE TRIP/ CURRENT LIMIT:			POLARITY	1	(+) = "0" (-) = "1"
LOCAL/REMOTE	1	LOCAL = "0" REMOTE = "1"	CROWBAR	1	OFF = "0" ON = "1"
CURRENT LIMIT: REMOTE LIMIT LEVEL	4	CODING MA 8421 1.0 = 0000 10 = 0001 20 = 0010 30 = 0011	OPERATE FLAG OUTPUT	1	CONTACTS CLDSED IN OPERATE MODE
			CURRENT LIMIT FLAG OUTPUT	1	CONTACTS OPEN IN NORMAL OPERA- TION
			VOLTAGE TRIP FLAG	1	CONTACTS OPEN IN NORMAL OPERA- TION

panel output, guard, and chassis connections are duplicated on the rear panel.

#### OPERATION:

Local via front panel controls or remote via program input; selectable at front panel.

#### RESPONSE TIME:

- 1, 10, 100 ma Ranges - 300 milliseconds typical - dependent on load resistance.
- 10V Range - 60 milliseconds.
- 100V Range - 300 milliseconds
- 1000V Range - 3 seconds.

#### NOTE

*When on the 1000V range, maximum repetition rate of a sequentially programmed instruction should not exceed the time intervals contained in Figure 1-1.*

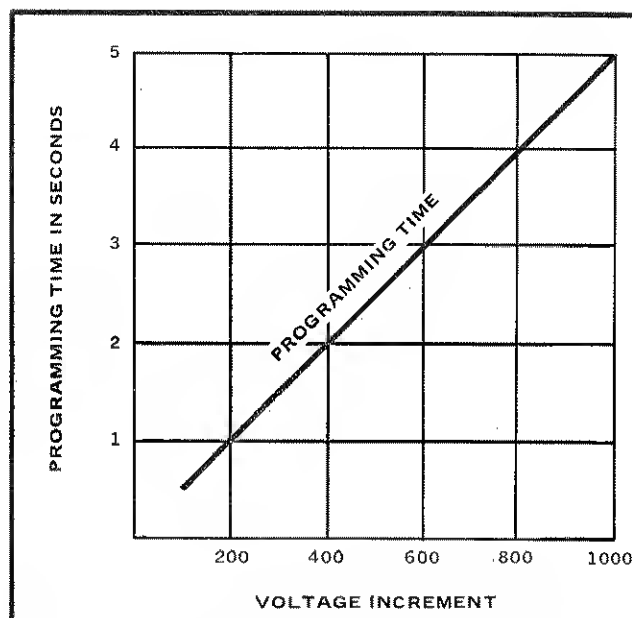


Figure 1-1. ALLOWABLE PROGRAMMING INTERVALS, 1000V RANGE AND CURRENT MODE

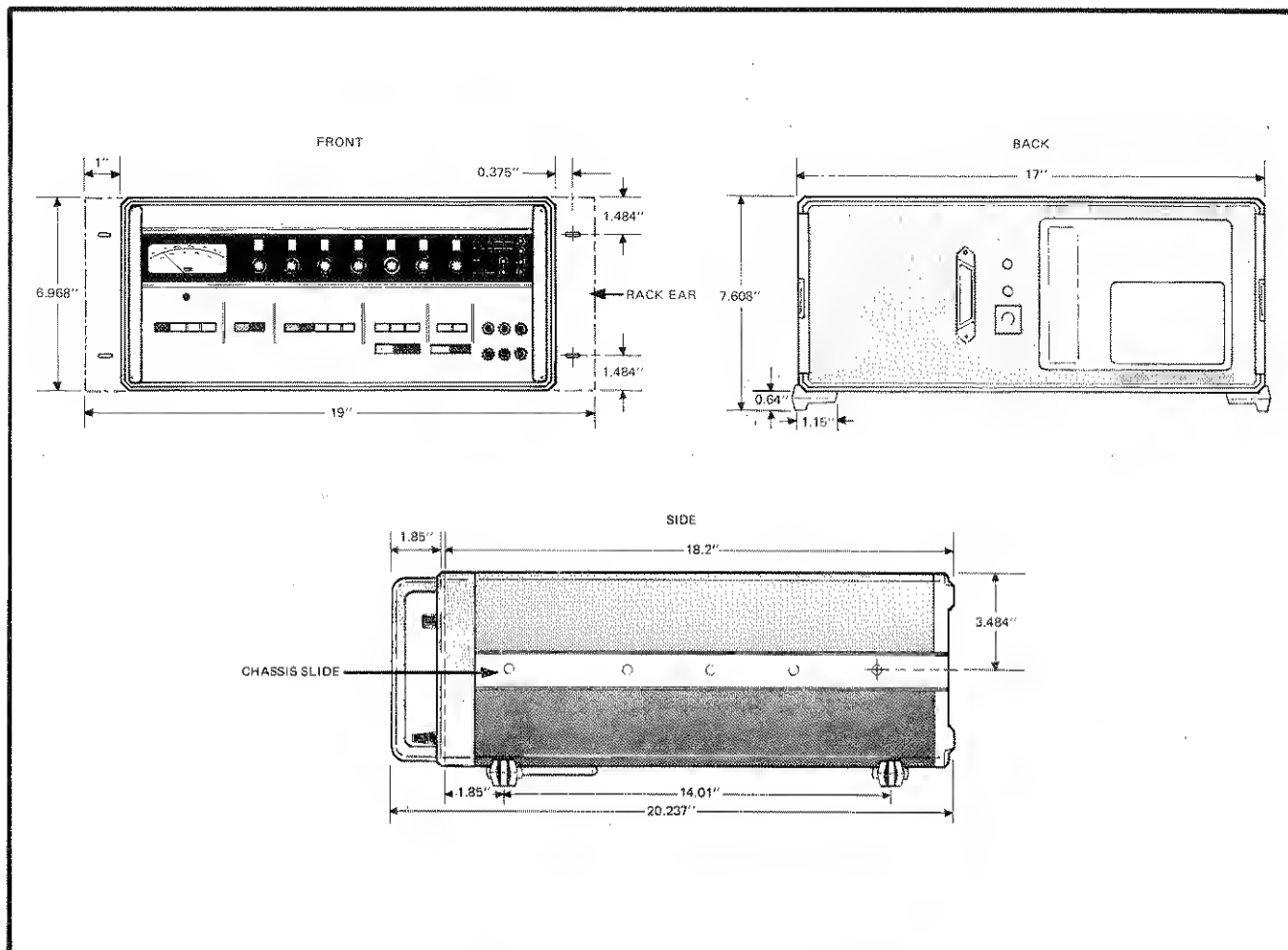


Figure 1-2. MODEL 3330B OUTLINE DRAWING

## TEMPERATURE:

OPERATING - 0° to +50°C  
NON-OPERATING - -40°C to +65°C

## RELATIVE HUMIDITY:

0 to 70%

## SHOCK:

15 g, 11 millisecond half-sine wave (MIL-T-21200)

## VIBRATION

10 Hz to 55 Hz, 3g maximum (MIL-T-21200)

## ALTITUDE:

OPERATING - 0 to 10,000 ft.  
NON-OPERATING - 0 to 50,000 feet

## INPUT POWER:

115/230 VAC  $\pm 10\%$ , 48 to 62 Hz single phase at  
approximately 130 VA fully loaded.

## SIZE:

7" high x 17" wide x 18" deep

## WEIGHT:

58 pounds

## MOUNTING:

Bench: Self-supported or included custom-  
designed feet.

Rack: Accepts optional brackets MEE-7003 for  
19" rack mounting and optional 18"  
chassis slides MEE-8078 (24" slides also  
available).





## Section 2

# Operating Instructions

### 2-1. INTRODUCTION

2-2. This section of the manual contains information essential to the correct operation and performance of the Model 3330B. It is recommended that the contents of this section be thoroughly read and understood before attempting to operate the instrument. Should any difficulties be encountered during the operation of your instrument, please feel free to contact the nearest John Fluke Sales Representative or the John Fluke Mfg. Co., Inc., Box 43210, Mountlake Terrace, WA 98043. A complete list of Sales Representatives is located in Section 7 of this manual.

### 2-3. Claim For Damage In Shipment

2-4. The Instrument should be thoroughly inspected immediately upon receipt. All material in the container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to the John Fluke representative. Upon receipt of this report you will be advised of the disposition of the equipment for repair or replacement. Include the model number, type number, and serial number when referring to this instrument for any reason.

### 2-5. Shipping Instructions

2-6. All John Fluke Mfg. Co., Inc. instruments should be shipped prepaid in the original packing carton. Upon request, a new carton can be obtained from the John Fluke Mfg. Co., Please include the instrument model number when requesting a new container.

### 2-7. RACK MOUNTING PROCEDURES

2-8. Accessory kits are available to provide for installation of the instrument in rack or sliding mounts.

2-9. To install the rack mounting ears (MEE-7003), perform the following steps in conjunction with Figure 2-1.

- a. Remove the four molded feet and the bail from the bottom cover.
- b. Remove the nameplate decals from the corner castings.
- c. Remove the screws from the corner castings that match the hole pattern in the rack mounting ears.
- d. Attach the rack mounting ears with pan head screws.

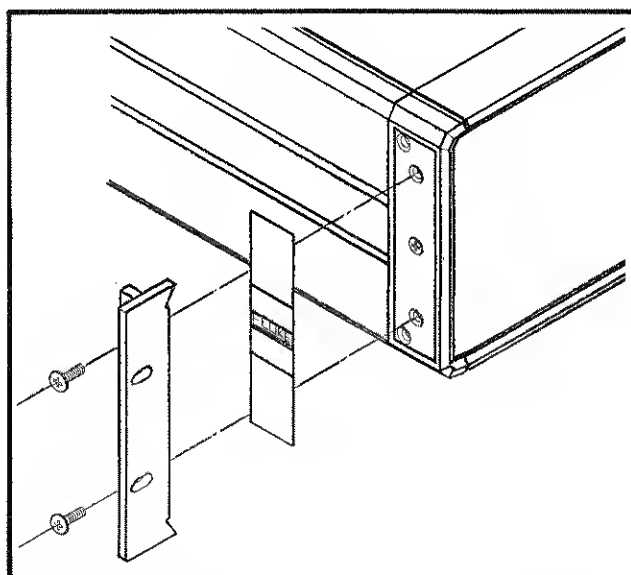


Figure 2-1. INSTALLATION OF RACK MOUNTING EARS

2-10. Perform the following steps to install the slide mounts (MEE-8078). Refer to Figure 2-2.

- a. Remove the plastic trim strips (A) from the side of the instrument by sliding it towards the rear.
- b. Attach the chassis section (B) of the slide and spacer strip (C) to the instrument using the center low mounting holes.
- c. Install cabinet section (E) and center section (D) of slide into rack. The extension angle bracket is provided.
- d. Extend center section (D) of slide towards you until it locks in the extended position.
- e. Depress the spring lock on chassis section (B) and insert the instrument between the extended slide sections.

## 2-11. INPUT POWER

2-12. The Model 3330B can be operated from either a 115 or 230 volt ac input. To convert from 115 to 230 VAC or vice versa, perform the following steps:

- a. Ensure that the line cord is disconnected from line power and then remove the top and bottom dust covers.
- b. Remove the jumpers between terminals 1 and 2, 3 and 4, or 2 and 3 of the input power transformer located on the bottom of the instrument. A decal located on the top of the transformer indicates location of the terminals. Refer to the illustrated parts list for location of the input power transformer.
- c. Make the following connections between the appropriate terminals of the power transformer:
 

<b>115 VOLTS AC</b>	<b>230 VOLTS AC</b>
Terminals 1 and 2	Terminals 2 and 3
Terminals 3 and 4	
- d. Replace the dust covers and install the following rated fuse in the rear panel fuseholder, F2:

<b>115 VOLTS AC</b>	<b>230 VOLTS AC</b>
3A, SLO-BLO	1.5A, SLO-BLO

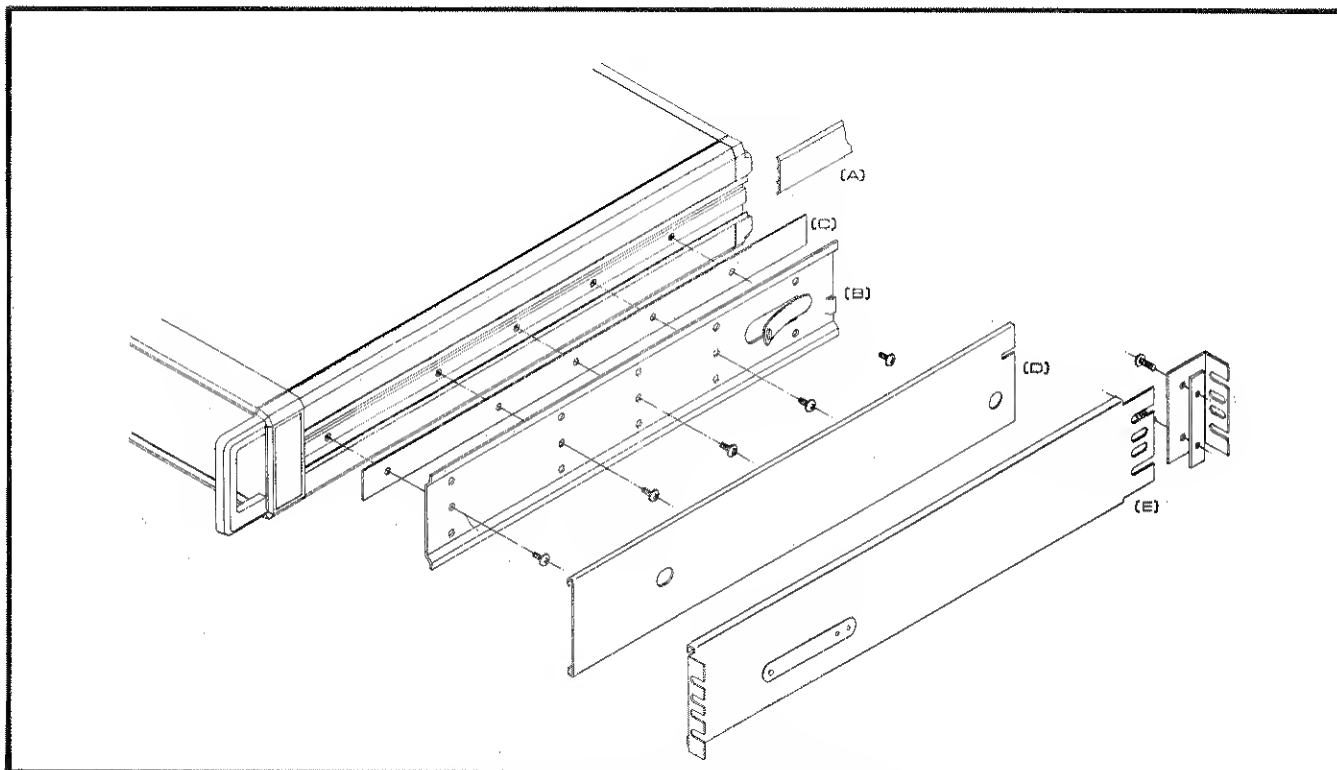


Figure 2-2. INSTALLATION OF SLIDE MOUNT

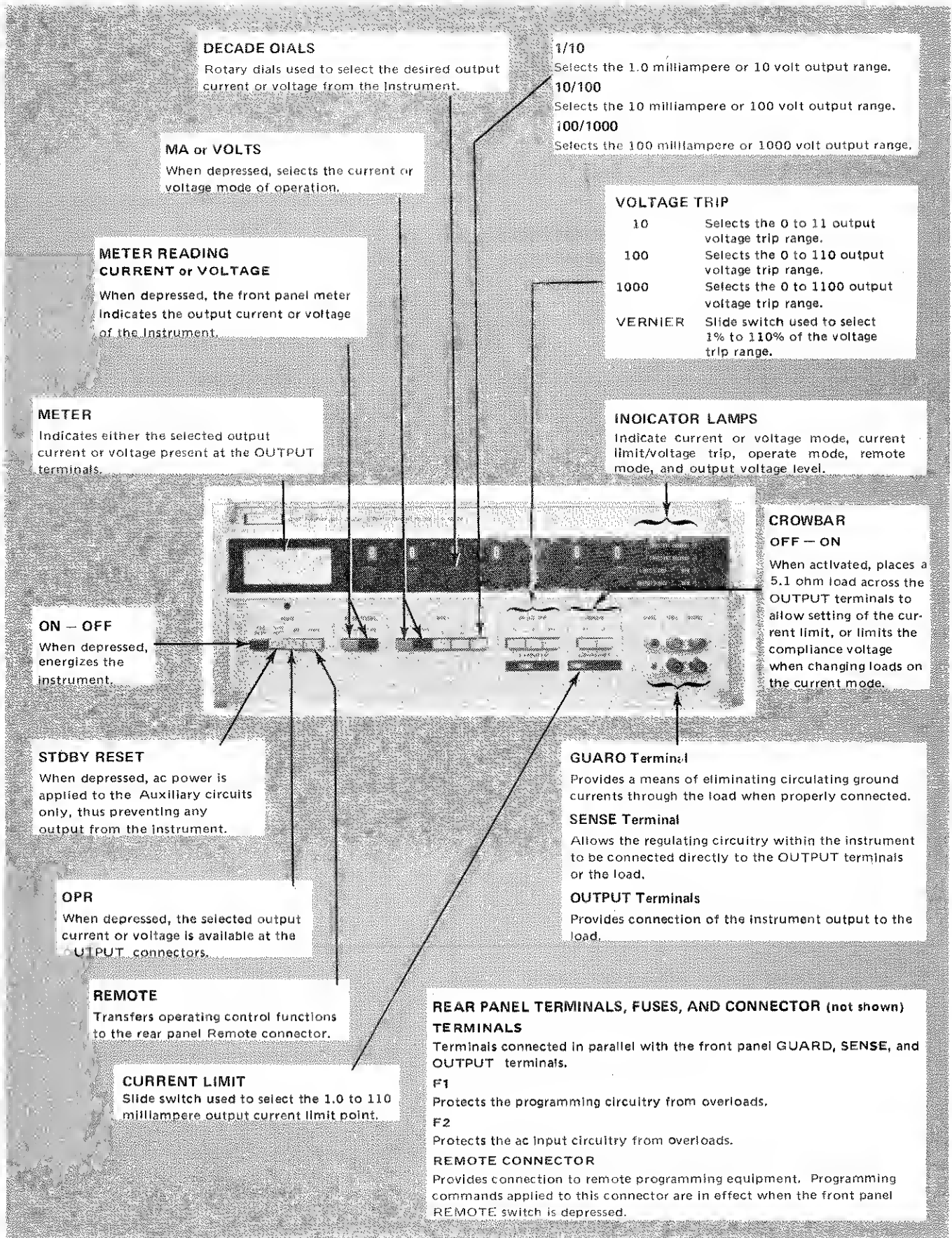


Figure 2-3. LOCATION OF CONTROLS, TERMINALS, AND INDICATORS

## 2-13. OPERATING FEATURES

2-14. Location and function of all controls, terminals, indicators, fuses, and connectors are contained in Figure 2-3.

## 2-15. PRELIMINARY PROCEDURES

2-16. The following paragraphs describe preliminary equipment connections, control settings, and safety precautions which should be taken before attempting to operate the Model 3330B.

## 2-17. AC Line Connection

- a. Connect the Model 3330B line cord to a 115 volt ac (230 volts ac, if so wired), 48 to 62 Hz, single phase three-wire outlet.

### WARNING

Ensure that the round pin on the three-prong line cord plug is connected to a high quality earth ground.

- b. Depress the ON-OEE and STDBY RESET switches.

## 2-18. Sense Terminal Connections

2-19. Whenever a load is connected to the Model 3330B there may be an appreciable voltage drop between the instrument and the load due to the resistance of the connecting cable leads. The nomograph illustrated in Figure 2-4 can be used to determine the approximate voltage drop within the connecting cable. If the voltage drop is excessive for the particular application, the instrument can be connected for remote sensing using the procedure described in paragraph 2-21.

### NOTE

*On all voltage ranges, the remote sense leads operate at a current level which varies from 0 to 1 mA in proportion to the output voltage. Voltage drops in the sense leads are additive and appear at the output as a voltage increase.*

### NOTE!

*The maximum allowable differential between an OUTPUT terminal and its respective SENSE terminal is  $\leq 0.5$  V dc.*

2-20. **NOMOGRAPH USE.** Lay a straight edge between the point representing the output current on scale 1 and the gauge of the connecting cable on scale 2. The voltage developed across connecting cable, in millivolts per foot, is then

read on scale 3. Calculate the total voltage drop by multiplying the total connecting cable length in feet by the scale 3 value. (A 5 foot cable will have a total connection length of 10 feet).

## 2-21. REMOTE SENSING TERMINAL CONNECTIONS.

- a. Depress the STDBY RESET switch.
- b. Remove the shorting links between the SENSE and OUTPUT terminals.
- c. Connect the + and - SENSE terminals to the respective positive and negative sides of the load. Use a twisted pair of insulated wires between the SENSE terminals and the load.

### CAUTION

Ensure that the SENSE terminals are connected in proper polarity to the load or a loss in regulation or even damage to the Model 3330B may occur. IF THIS REMOTE SENSING FEATURE IS NOT USED, THE SENSE TERMINALS MUST BE CONNECTED TO THE OUTPUT TERMINALS WITH THE SHORTING LINKS.

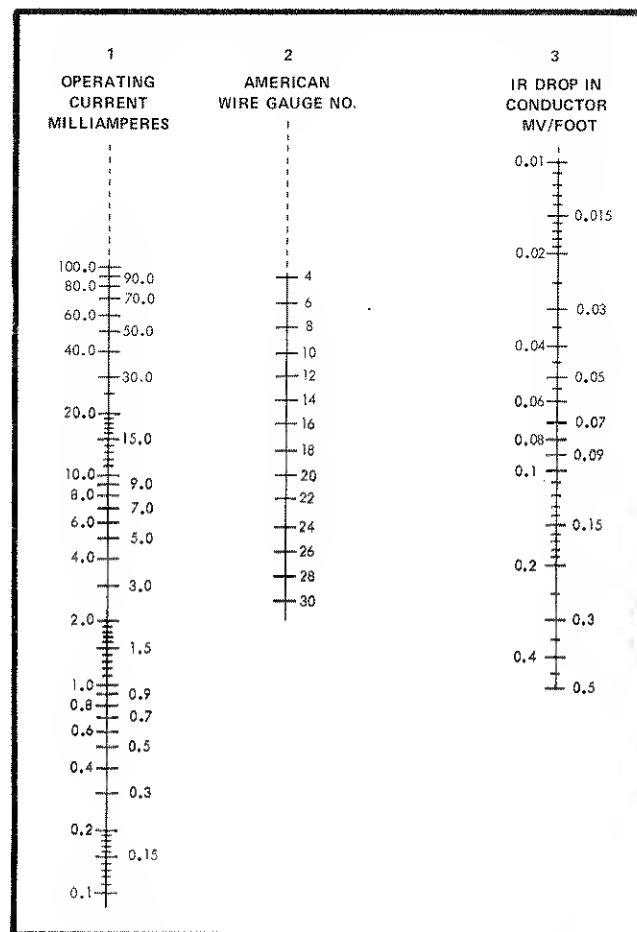


Figure 2-4. NOMOGRAPH OF VOLTAGE DROP ACROSS LOAD WIRES

## 2-22. Guarded Measurements

**2-23. INTRODUCTION.** When using the Model 3330B significant errors may arise out of undesired conversion of common mode signals to normal mode. This instrument has a guard shield that functions to minimize common mode-to-normal mode conversion. The following paragraphs describe errors that may arise out of common mode problems and provide a means to reduce them.

**2-24. COMMON MODE REJECTION RATIO (CMRR)** In non-guarded applications, a path for undesired common mode signals is created by the stray capacitance  $C_1$  (Figure 2-5) representing the circuitry-to-case capacitance in the instrument. This capacitance enables frequency dependent currents to appear in the connecting leads between the instrument and load, and in the instrument circuitry itself.

**2-25.** The guard shield provides a means of making the circuitry-to-case capacitance very small, thereby reducing common mode currents. This is done by placing a shield, or guard, between the circuitry and case. Addition of the guard results essentially in two things; it provides a separate path for common mode signals, and it effectively prevents the introduction of common mode errors in the circuitry itself. Where common mode signals previously had a path through  $C_1$  into the circuitry and connecting leads and through  $R_s$ , insertion of the guard now provides a separate path through  $C_3$  and into the guard lead. In addition, the circuitry-to-case capacitance is significantly reduced, and the CMRR of the instrument is greatly enhanced.

**2-26. SUGGESTIONS FOR USING THE GUARD.** Under most applications it is satisfactory to strap the front panel GUARD to the ground terminal of the load. In applications where common mode signals are of no concern, the GUARD may be connected to the  $\frac{1}{2}$  (ground) terminal.

## 2-27. Voltage Trip Settings

**2-28.** The VOLTAGE TRIP switch and VERNIER controls provide protection for external equipment by limiting the maximum allowable output voltage to the external load. The range of voltage limiting is selected with the VOLTAGE TRIP switches. Refinement of the value of the voltage to be limited is accomplished with the VERNIER control.

- Without any load connected to the OUTPUT terminals, depress the STDBY/RESET switch and set the front-panel controls to the following positions:

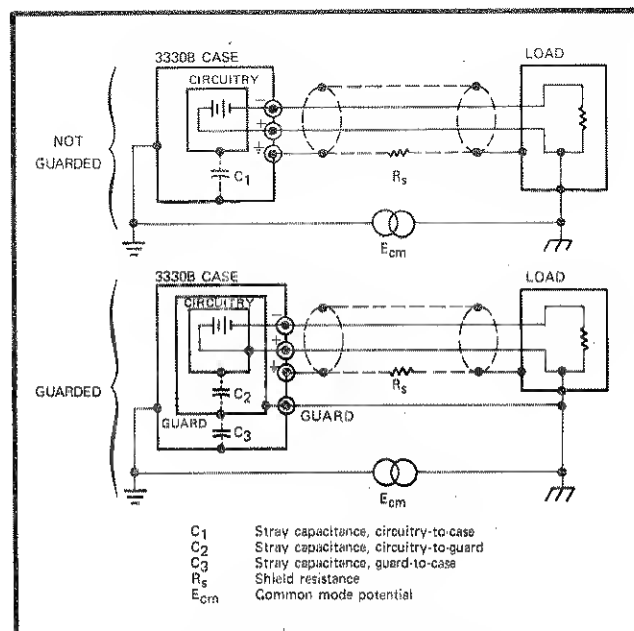


Figure 2-5. GUARDED LOAD CONNECTIONS

MODE	Desired voltage range
VOLTAGE TRIP	To the lowest voltage range that overlaps the desired trip voltage.
VERNIER	HI
CURRENT LIMIT	As desired
METER	VOLTAGE
Decade Dials	Desired trip voltage

- Depress the OPR switch.
- Slowly slide the VERNIER control to the left until the 1 LIMIT/V TRIP indicator illuminates and the OPR lamp extinguishes. The voltage trip is now set to the value indicated on the Decade Dials, and the instrument is tripped to the STDBY mode.
- To reset the instrument, set the Decade Dials to a value less than the trip voltage, depress the STDBY/RESET switch, and then depress the OPR switch.

## 2-29. Current Limit Settings

**2-30.** The CURRENT LIMIT control provides a means of limiting the amount of output current applied to the load. If limiting within the output current range of the instrument is not desirable, set the CURRENT LIMIT control to HI. Should some degree of current limiting be desirable, proceed as follows:

- Depress the STDBY RESET switch, and set the front panel controls to the following positions:

MODE	Desired current (MA) range
VOLTAGE TRIP	As desired. However, must be >10V for full scale output current. To set a precise level, use the voltage trip setting procedure, given earlier, and set the Decade Dials to:

42-43-45-47-49  
100V RANGE 310N

10x Output Current + desired voltage trip level  
Output Current Range

in paragraph 2-21. GUARD terminal connections are described in paragraph 2-22.

For example, at full scale current output, a precise 5V trip level is established by setting the Decade Dials to 15.

#### CURRENT LIMIT LO

METER CURRENT

Decade Dials As required

- b. Depress the CROWBAR ON and OPR switches.
- c. Slide the CURRENT LIMIT control to the right until the desired maximum output current is indicated on the front panel meter.
- d. Depress the STDBY RESET switch and then depress the CROWBAR OFF switch. Current limiting is now set to the desired value for any output setting of the instrument.

### 2-31. FRONT PANEL OPERATING PROCEDURES.

2-32. The Model 3330B can be operated as a voltage or current source by performing the following steps:

- a. Depress the ON-OFF and STDBY RESET switches. Allow the instrument circuitry to stabilize for at least 10 minutes if it has not been previously energized.
- b. Connect the SENSE terminals to the OUTPUT terminals using the shorting links provided with the instrument.
- c. Set the Current Limit and Voltage Trip to the desired values using the procedures described in paragraphs 2-27 and 2-29.
- d. Depress the STDBY/RESET switch and select the desired current or voltage range with the MODE switches.
- e. Set the Decade Dials to the desired output current or voltage value.
- f. Connect the load to the OUTPUT terminals. If remote sensing is desired, connect the SENSE terminals to the load using the procedures described

### WARNING

The Model 3330B has a compliance voltage capability of 1100 volts dc. Always connect the load with the instrument in STDBY/RESET.

- g. Depress the OPR switch to energize the load. The output current or voltage can be monitored at any time on the front panel meter by depressing the appropriate METER READING switch.

### 2-33. REMOTE OPERATION

2-34. Remote programming of the Model 3330B is possible through the rear panel Remote connector using either DTL/TTL logic and 8-4-2-1 coding or contact closures. A mating connector for the remote connector is furnished with the instrument to provide the necessary circuit interface. Table 2-1 contains a list of the Remote connector terminals and their functions. Coding information is located in Section 1, Table 1-1.

Table 2-1. REMOTE CONNECTOR TERMINALS AND FUNCTIONS (Sheet 1 of 2)

TERMINAL	FUNCTION
1	1 — Highest Order Decade
2	2 — Highest Order Decade
3	4 — Highest Order Decade
4	8 — Highest Order Decade
5	1 — Second Order Decade
6	2 — Second Order Decade
7	4 — Second Order Decade
8	8 — Second Order Decade
9	1 — Third Order Decade
10	2 — Third Order Decade
11	4 — Third Order Decade
12	8 — Third Order Decade
13	1 — Fourth Order Decade
14	2 — Fourth Order Decade
15	4 — Fourth Order Decade
16	8 — Fourth Order Decade
17	1 — Fifth Order Decade
18	2 — Fifth Order Decade
19	4 — Fifth Order Decade
20	8 — Fifth Order Decade
21	1 — Sixth Order Decade
22	2 — Sixth Order Decade
23	4 — Sixth Order Decade
24	8 — Sixth Order Decade

Table 2-1. REMOTE CONNECTOR TERMINALS AND FUNCTIONS (Sheet 2 of 2)

TERMINAL	FUNCTION
25	1 - Seventh Order Decade
26	2 - Seventh Order Decade
27	4 - Seventh Order Decade
28	8 - Seventh Order Decade
29	Logic "0" - 10V/1 MA Range Logic "1" - 100V/10 MA Range
30	Logic "0" - Voltage Mode Logic "1" - Current Mode
31	Logic "0" - 10V/1 MA or 100V/10 MA Range Logic "1" - 1000V/100MA Range
32	
33	Logic "0" - Standby Mode Logic "1" - Operate Mode
34	Logic "0" - Crowbar Mode Off Logic "1" - Crowbar Mode On
35	Logic "0" - Positive Polarity Output Logic "1" - Negative Polarity Output
36	Program Common
37	'Operate' Flag
38	Logic "0" - Front Panel Voltage Trip and Current Limiter Control Logic "1" - Remote Voltage Trip and Current Limiter Control
39	1 - 10% Voltage Trip Vernier
40	2 - 20% Voltage Trip Vernier
41	4 - 40% Voltage Trip Vernier
42	8 - 80% Voltage Trip Vernier
43	8 - 80% - Current Limit Vernier
44	4 - 40% - Current Limit Vernier
45	2 - 20% - Current Limit Vernier
46	1 - 10% - Current Limit Vernier
47	1 KV Voltage Trip Range
48	100V Voltage Trip Range
49	Current Limit Flag
50	Voltage Trip Flag

2-35. Activation of the remote control feature is accomplished by first energizing the instrument while in STDBY RESET or by selecting STDBY RESET, and then selecting the REMOTE mode of operation. Control is then transferred to the rear Panel Remote connector where either transistor logic level programming or contact closures can

For Remote Program 36-Common Terminal  
2-38-33-1-2-8-4 For VBD, 3330B  
Range 50-100-12-43

be used to control the operating modes of the instrument. Logic "1" is 0 to 0.5 volts dc or a short circuit, and Logic "0" is +4.5 to 20 volts dc or an open circuit. Short circuit current to programming common is less than 4.0 milliamperes. Open circuit voltage is 4 to 6 volts dc.

2-36. Excessive output level changes will result in triggering of the Voltage Trip circuitry, especially on the 1000 volt range. In this event the 3330B must be manually reset using the STDBY RESET Switch. Safe programming rates are listed below. Figure 1-1 located in Section 1 shows recommended 1000V range programming rates below 1000 volts.

- a. 1000 volt range 1 programming change every 5 seconds for 1000 volt change.
- All current ranges: 1 programming change every 5 seconds for a 1000V change.

2-37. Accuracy of the Model 3330B output is also affected by the magnitude of the programming changes. Figure 2-6 shows typical output accuracies in relation to 1/10th to full-scale voltage changes.

## 2-38. PROGRAMMING NOTES

### 2-39. Introduction

2-40. Successful programming of the 3330B calibrator requires knowledge of the timing involved and an awareness of control line definitions. The following paragraphs contain notes which will be of value in programming, plus timing information for proper instrument control.

### 2-41. Decade Dials

2-42. Programming of each Decade Dial is accomplished using 8-4-2-1 coding. The maximum digit that can be programmed on each decade is 10, using a "1010" code. Maximum remote controlled output is 111.11110 milliamperes and 1111.1110 volts dc.

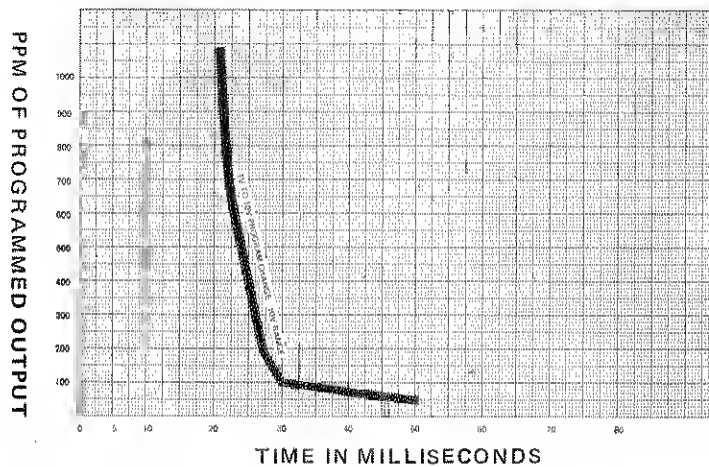
### 2-43. Polarity

2-44. A Logic "1" applied to the proper programming terminal will reverse the output polarity at both the front and rear terminals of the instrument.

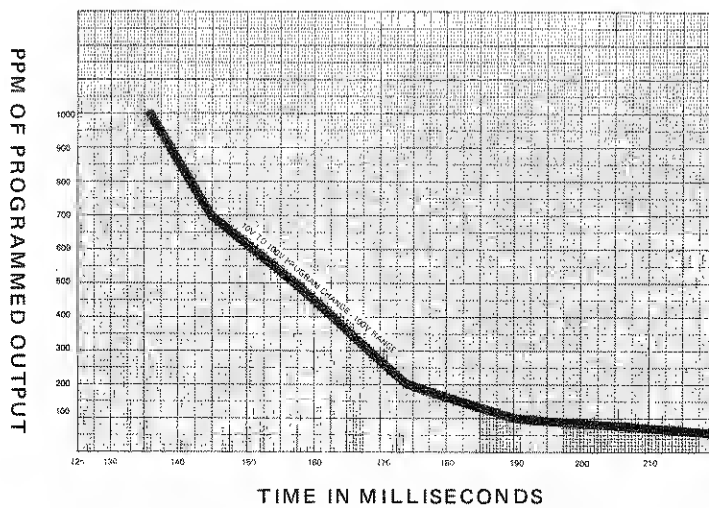
### 2-45. Voltage/Current Limit Vernier

2-46. Programming of the Voltage or Current Vernier is accomplished using 8-4-2-1 coding. The minimum

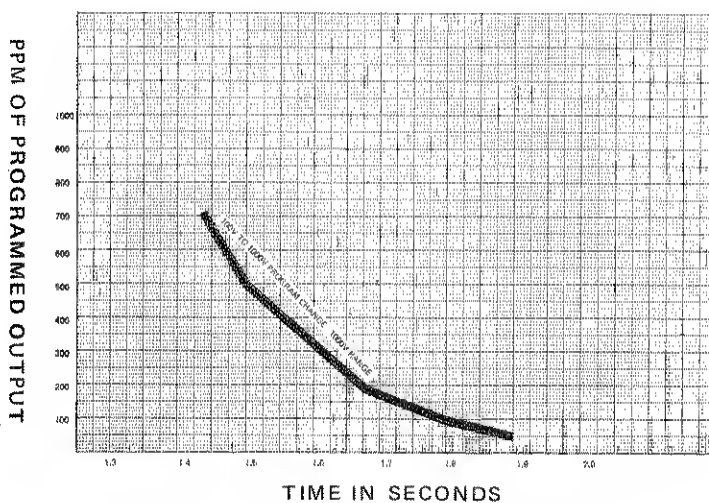




OUTPUT ACCURACY FOR A 1V TO 10V PROGRAM CHANGE — 10V RANGE



OUTPUT ACCURACY FOR A 10V TO 100V PROGRAM CHANGE — 100V RANGE



OUTPUT ACCURACY FOR A 100V TO 1000V PROGRAM CHANGE — 1000V RANGE

Figure 2-6. OUTPUT ACCURACY VERSUS PROGRAM CHANGE TIME

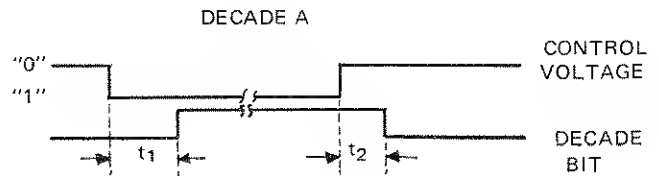


**DECADE PULL-IN TIME:** THE PERIOD REQUIRED TO ELECTRICALLY ADD A DECADE BIT TO THE CIRCUITRY AFTER THE PARTICULAR BIT HAS BEEN ACTIVATED BY AN EXTERNAL CONTROL VOLTAGE.

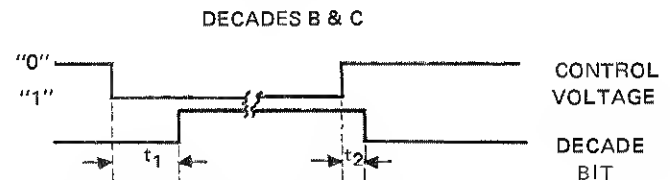
DECADE A	- 15 MS
DECADE B & C	- 10 MS
DECADE D-G	- 2 MS

**DECADE DROP-OUT TIME:** THE PERIOD REQUIRED TO ELECTRICALLY DROP A PARTICULAR DECADE BIT FROM THE CIRCUITRY AFTER REMOVING ITS EXTERNAL CONTROL VOLTAGE.

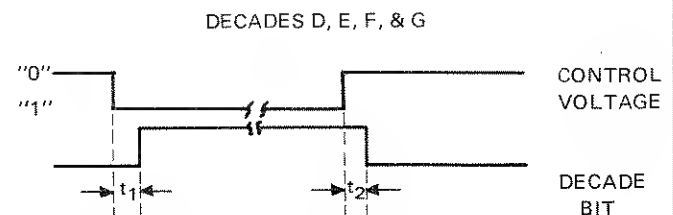
DECADE A	- 12 MS
DECADE B & C	- 3 MS
DECADE D-G	- 3 MS



PULL-IN TIME ( $t_1$ ) = 15 ms TYPICALLY  
DROP-OUT TIME ( $t_2$ ) = 12 ms TYPICALLY



PULL-IN TIME ( $t_1$ ) = 10 ms TYPICALLY  
DROP-OUT TIME ( $t_2$ ) = 3 ms TYPICALLY



PULL-IN TIME ( $t_1$ ) = 2 ms TYPICALLY  
DROP-OUT TIME ( $t_2$ ) = 3 ms TYPICALLY

**SETTLING TIME:** THE TOTAL TIME REQUIRED FOR THE INSTRUMENT TO SETTLE TO ITS RATED ACCURACY WITHIN A PARTICULAR RANGE AND MODE OF OPERATION.

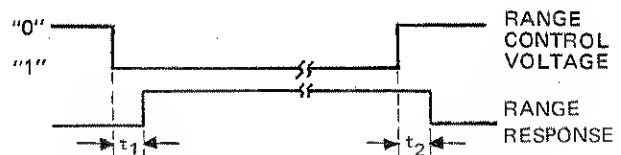
**VOLTAGE MODE:**

10V RANGE	- 60 MS
100V RANGE	- 300 MS
1000V RANGE	- 3 SEC.

**CURRENT MODE:**

1 MA RANGE	- 300 MS
10 MA RANGE	- 300 MS
100 MA RANGE	- 300 MS

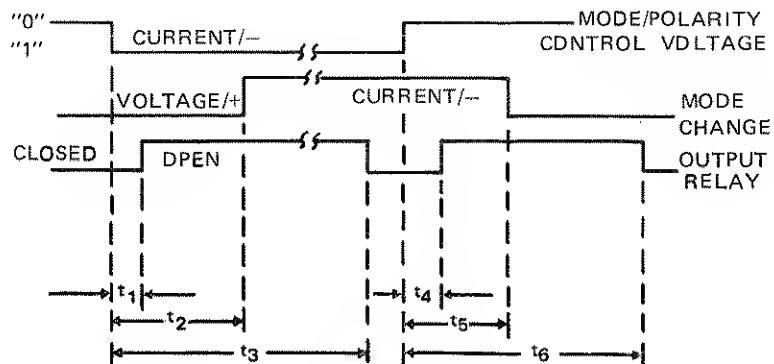
**RANGE CHANGE TIME:** THE PERIOD OF TIME BETWEEN APPLICATION OF AN EXTERNAL RANGE CONTROL VOLTAGE AND WHEN THE PARTICULAR RANGE IS ADDED ELECTRICALLY TO THE CIRCUIT (10ms).



PULL-IN TIME ( $t_1$ ) = 15 ms TYPICALLY  
DROP-OUT TIME ( $t_2$ ) = 5 ms TYPICALLY

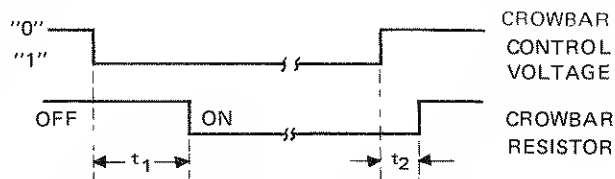
Figure 2-7. TIMING INFORMATION (Sheet 1 of 3)

**POLARITY AND MOOE CHANGE TIME:**  
THE PERIOD OF TIME BETWEEN APPLI-  
CATION OF AN EXTERNAL CONTROL  
VOLTAGE AND WHEN THE OUTPUT  
RELAY CONTACTS REMOVE THE SHORT  
ACROSS THE OUTPUT TERMINALS. (See  
Crowbar Time) (130 ms).



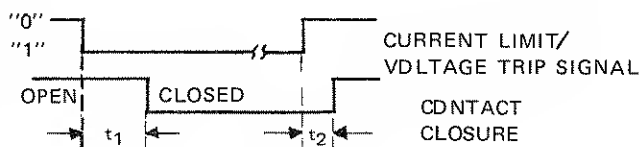
PULL-IN TIME ( $t_2$ ) = 45 ms TYPICALLY  
PULL-IN TIME ( $t_3$ ) = 100 ms TYPICALLY  
PULL-IN TIME ( $t_6$ ) = 80 ms TYPICALLY  
DROP-OUT TIME ( $t_1$ ) = 10 ms TYPICALLY  
DROP-OUT TIME ( $t_4$ ) = 10 ms TYPICALLY  
DROP-OUT TIME ( $t_5$ ) = 50 ms TYPICALLY

**CROWBAR TIME:** THE PERIOD BETWEEN APPLI-  
CATION OF AN EXTERNAL CONTROL VOLTAGE AND  
WHEN THE CROWBAR RESISTOR APPEARS ELECTRIC-  
ALLY ACROSS THE OUTPUT TERMINALS (15 ms).



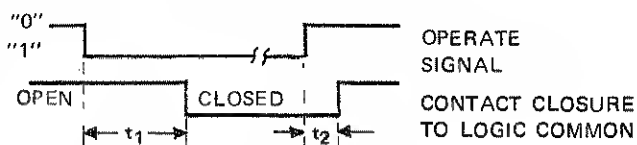
PULL-IN TIME ( $t_1$ ) = 15 ms TYPICALLY  
DROP-OUT TIME ( $t_2$ ) = 5 ms TYPICALLY

**CURRENT LIMIT AND VOLTAGE TRIP FLAG TIME:**  
THE PERIOD BETWEEN THE OVER-CURRENT OR OVER-  
VOLTAGE CONDITION AND A CONTACT CLOSURE  
TO LOGIC COMMON AT THE PROGRAMMING CON-  
NECTOR. (2 ms).



PULL-IN TIME ( $t_1$ ) = 2 ms TYPICALLY  
DROP-OUT TIME ( $t_2$ ) = 1 ms TYPICALLY

**OPERATE FLAG TIME:** THE PERIOD OF TIME BE-  
TWEEN DEPRESSION OF THE OPERATE SWITCH AND  
A CONTACT CLOSURE TO COMMON AT THE PRO-  
GRAMMING CONNECTOR. (15 ms).



PULL-IN TIME ( $t_1$ ) = 15 ms MAXIMUM  
DROP-OUT TIME ( $t_2$ ) = 5 ms TYPICALLY

**RESET TIME:** THE PERIOD OF TIME THE "OPERATE"  
LINE MUST BE HELD AT LOGIC "0" IN ORDER TO  
ELECTRICALLY RESET THE INSTRUMENT. (10 ms).  
(Refer to "NDTE" of paragraph 2-54).



MINIMUM RESET TIME ( $t_1$ ) = 10 ms TYPICALLY

Figure 2-7. TIMING INFORMATION (Sheet 2 of 3)

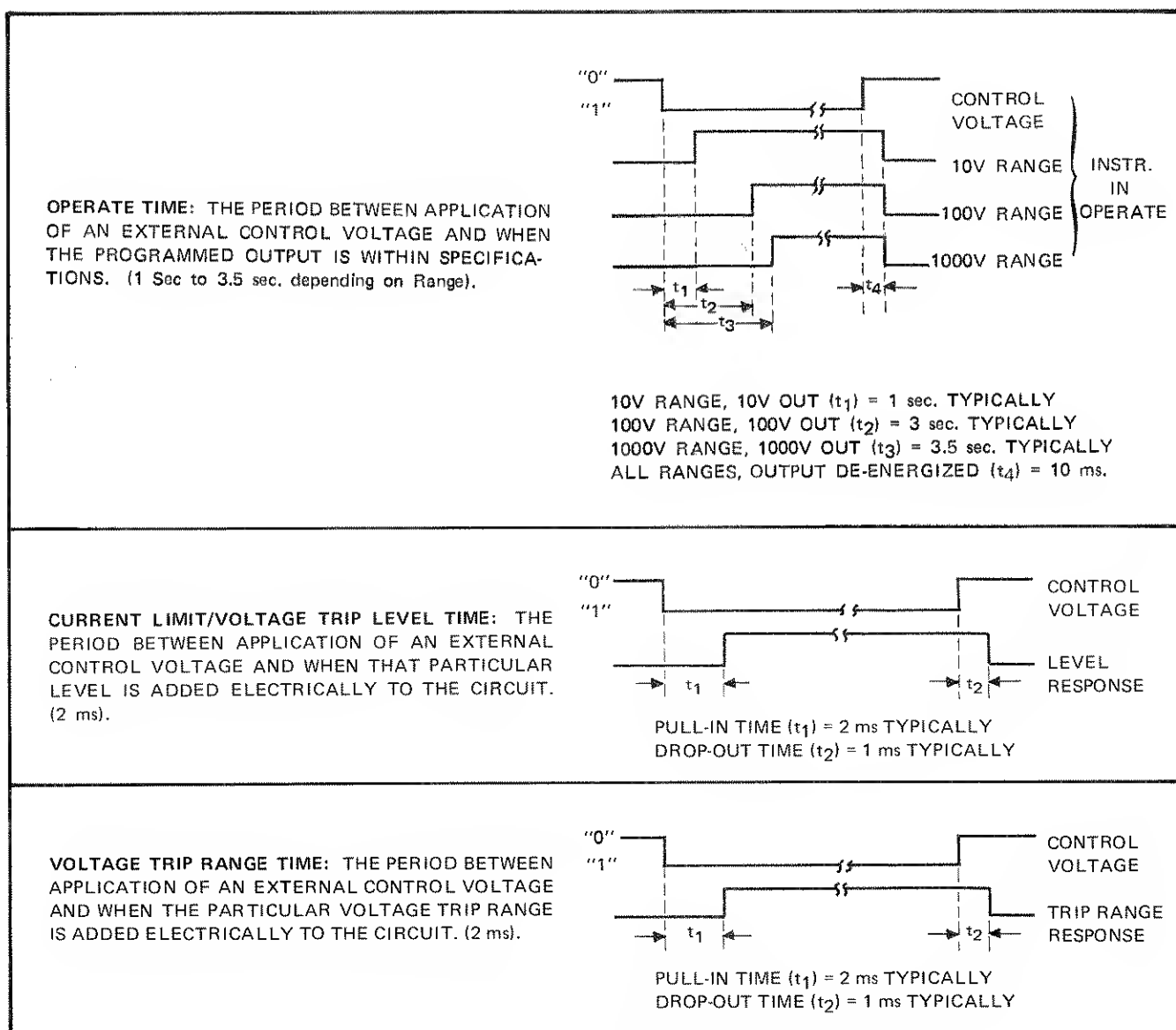


Figure 2-7. TIMING INFORMATION (Sheet 3 of 3)

vernier voltage or current limit value that can be programmed is 10% of the selected range using a "0001" code. Maximum vernier limit value is 110% of the selected range using a "1011" code.

## 2-47. Voltage Trip Range

2-48. Programming of the Voltage Trip Range may be accomplished by applying Logic "1" to the proper programming terminals. The Voltage Trip is normally in the 10V range with program lines at Logic "0". Whenever the Voltage Trip Feature is triggered, the instrument is automatically tripped to the STDBY/RESET mode. Logic "0" must then be applied to terminal 33, followed by Logic "1" to return the instrument to OPERATE. Refer to paragraph 2-54 for resetting information.

11/72

## 2-49. Flag Indicator Outputs

2-50. Isolated flag indicator outputs are available at the Remote connector to provide an indication of the Operate/Voltage Trip, or Current Limit modes of operation. Terminal 50 is the Voltage Trip Flag, terminal 49 is the Current Limit Flag, and terminal 37 is the Operate Flag. If a polarity or mode change is programmed, a standby state will be indicated for approximately 100 milliseconds. Each flag is a contact closure to terminal 36, Program Common.

## 2-51. Timing Information

2-52. Figure 2-7 contains timing definitions and waveforms which will be of assistance in programming the Model

2-11

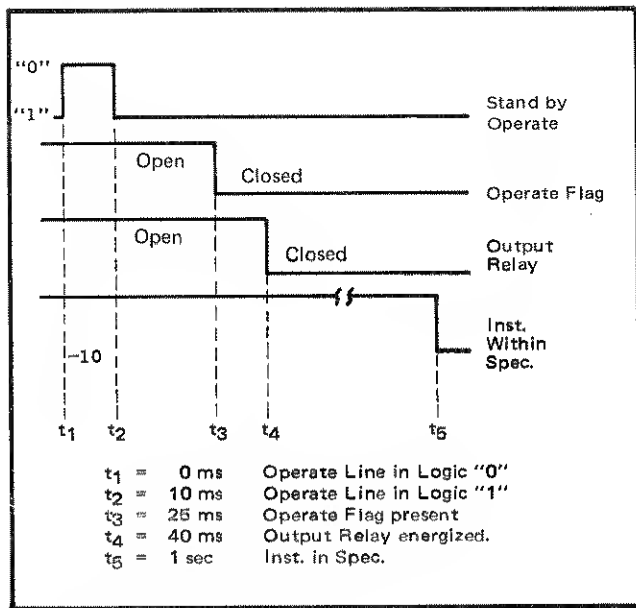


Figure 2-8. TYPICAL RESET ON 10V RANGE

3330B. Pay particular attention also to the special operating considerations outlined in paragraph 2-53.

### 2-53. Special Operating Conditions

2-54. **RESETTING.** The operate line must be held in a Logic "0" state for a minimum of 10 ms before Logic "1" may be applied. Actual resetting is accomplished as soon as the operate line is returned to Logic "0". When a Logic "1" is applied, the output becomes energized.

#### NOTE

*Resetting is not possible for a period of five seconds if the instrument is in a voltage trip condition due to excessive application of the automatic crowbar. Refer to paragraphs 3-70 and 3-74.*

2-55. **CURRENT MODE.** When switching from low to high compliance voltages, programming speeds must be slower. This applies when using compliance voltages in excess of 200 volts; programming rates should not exceed the times shown in Figure 1-1, Section I.

2-56. **VOLTAGE MODE.** Range or programming changes within the 1 kv range must be made at rates within the times shown in Figure 1-1; this applies when output voltages are greater than 200 volts.

2-57. **CURRENT LIMIT/VOLTAGE TRIP FLAGS.** The current and voltage flags will not be enabled and consequently cannot be present at the programming connector until approximately 40 ms after the instrument is in the operate mode. Also, there will be an absence of both flags for approximately 100 ms during either a mode or polarity change, due to the instrument being placed in standby during this time.

2-58. **OPERATE FLAG.** A contact closure to program common will be present approximately 15 ms after the instrument is commanded to the operate mode. The output relay does not energize for another 15 ms; see Figure 2-8. During a polarity or mode change, the output relay will open for 100 ms and then close.

2-59. **VOLTAGE TRIP RANGE.** When programming the Output Voltage and Voltage Trip range from some high level to a low level, it must be remembered that the Voltage Trip Range time is much less than the Output Voltage settling time. If both are programmed down simultaneously, the instrument will trip into the Voltage Trip mode. Allow sufficient time after programming the output from a high level to a low level before programming the Voltage Trip Range from a high level to a low level. In a worst-case application, with the instrument operating on the 1000 volt range, if all the decades are

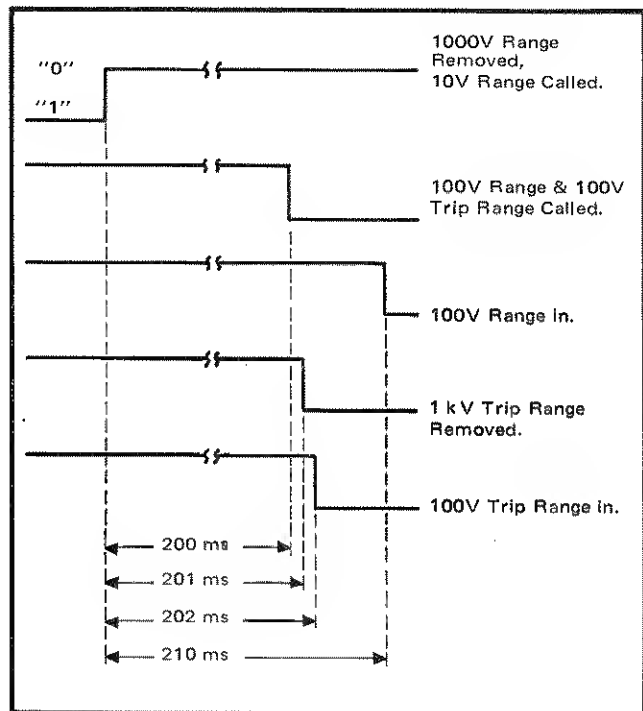


Figure 2-9. 1 KV to 100V TRIP TIMING

programmed to zero, allow 3 seconds before programming the Voltage Trip Range to a lower range.

2-60. To program the Voltage Trip Range from the 1000V range to the 100V range, first down-range the instruments' output to the 10V range. Then, 200 ms after the instrument has been down-ranged, program the 100V range and the 100V Voltage Trip Range simultaneously. Refer to Figure 2-9.

## 2-61. Operating Examples

2-62. The use of an output crowbar when using the current mode is normal procedure, since the crowbar is used when changing loads in the current mode. As pointed out in Figure 2-7, 15 ms is required before the crowbar actuates. Therefore, 15 ms of time is required before removing or changing loads. If this procedure is not followed, the instrument will slew up to the voltage trip point.



## Section 3

# Theory of Operation

### 3-1. INTRODUCTION

3-2. This section of the manual contains the theory of operation for the Model 3330B. The information is arranged under headings of "ASSEMBLY NUMBERING SYSTEM, FUNDAMENTAL CIRCUIT DESCRIPTION, GENERAL CIRCUIT ANALYSIS, and CIRCUIT DESCRIPTIONS". An equivalent circuit of the instrument is illustrated in Figure 3-2. A system block diagram and schematic diagrams are located in Section 8 of the manual.

### 3-3. ASSEMBLY NUMBERING SYSTEM.

#### 3-4. General

3-5. The following assembly numbering system has been employed in the Model 3330B to identify specific assemblies and their electrical components.

#### 3-6. Assembly Reference Designations.

3-7. The Model 3330B is divided into major parent assemblies designated the letter number A1 through A7. These assemblies and their respective titles are:

A1	Front Panel
A2	Rear Panel
A3	Front Mother Board
A4	Main Mother Board
A5	Rear Mother Board
A6	Relay Board
A7	Inner Chassis

3-8. Assemblies contained within major assemblies are also identified by a letter number designation. For example,

the Chopper Amplifier located on the A4 Main Mother Board has been assigned the letter number A2. Complete identification of this assembly is A4A2.

3-9. Components located on each assembly are designated the appropriate letter number Q1, C1, R1, etc. For example, the MOS FET transistor on the Chopper Amplifier is designated the letter number Q1. Complete identification of a component is then possible by preceding its reference designation by the assembly designation. In the preceding example, Q1 is completely identified by the designation A4A2Q1.

#### 3-10. Assembly Identifiers

3-11. During the manufacturing processes, assembly identifiers have been assigned to the completed printed circuit boards. A printed circuit board may be identified by a 3000 series number that is silk-screened on the land pattern side of the assembly, or by a six-digit FLUKE part number located on the component side.

#### 3-12. Schematic Diagram Identifiers

3-13. Figure 3-1 contains a chart which lists all of the diagrams associated with this instrument. These diagrams are located at the rear of the manual.

#### 3-14. FUNDAMENTAL CIRCUIT DESCRIPTION.

3-15. The circuitry of the Model 3330B consists basically of a high-gain operational amplifier such as the one shown in Figure 3-2. A precision reference voltage fur-

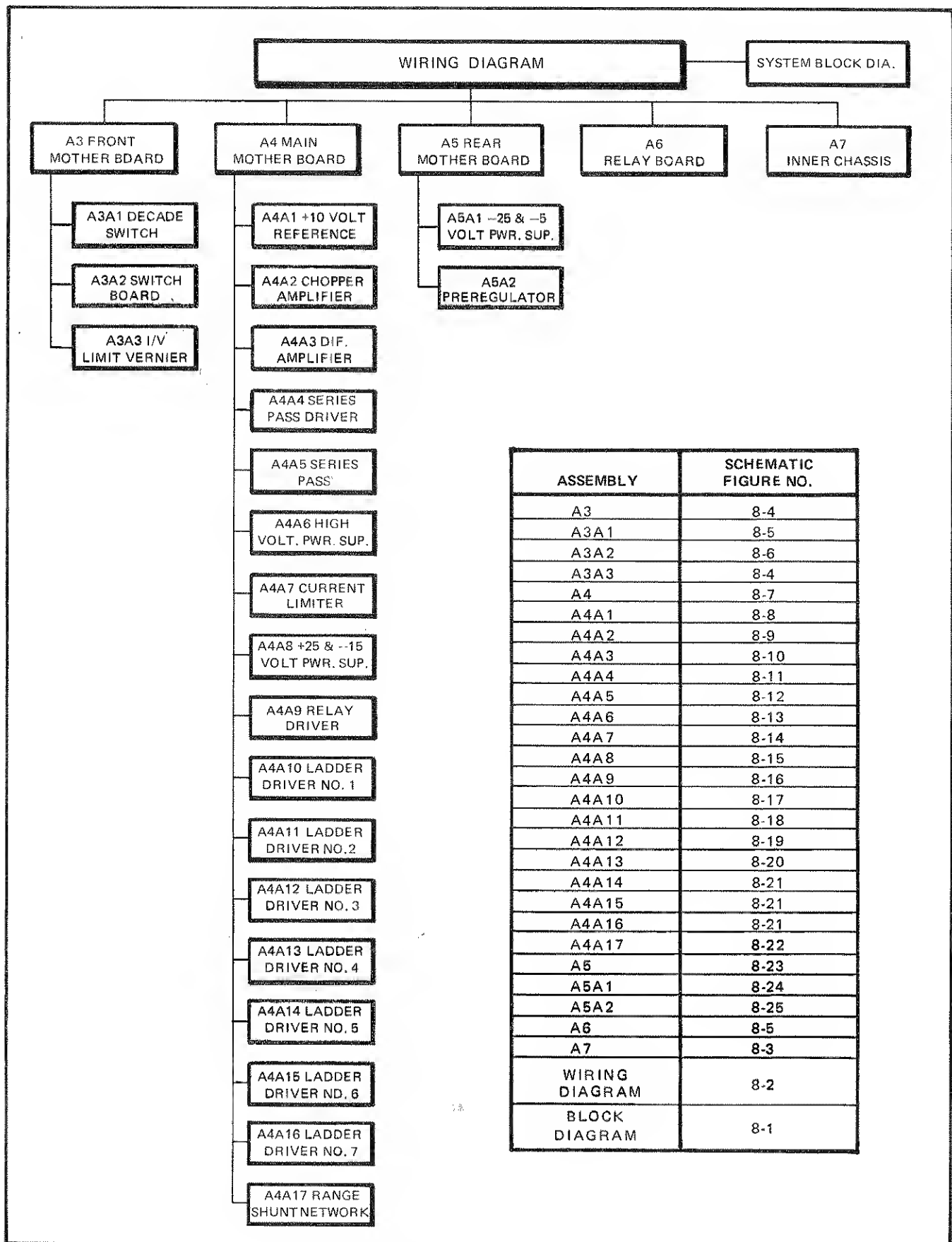


Figure 3-1. MODEL 3330B DIAGRAMS



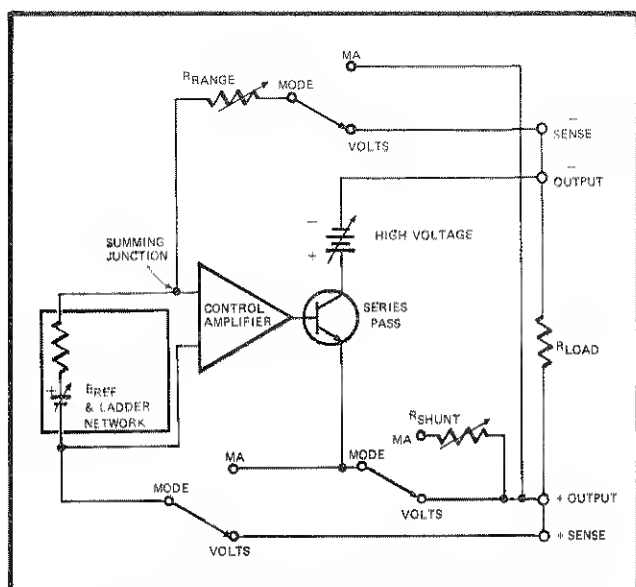


Figure 3-2. BASIC INSTRUMENT CIRCUITRY  
(DRAWN WITHOUT THE PREREGULATION LOOP)

nished by the reference supply and ladder network provides a current through the range resistor equal to the dialed output. The voltage developed across the range resistor furnishes a signal to the control amplifier that determines the rate of conduction of the series pass element. The conduction level of the series pass element then establishes the appropriate output voltage or current.

3-16. Two major loops actually form the instrument circuitry. One loop consists of an ac pre-regulator and the other is the main dc regulator. Each of these loops is described separately in the following paragraphs.

### 3-17. Voltage Mode

3-18. **PRE-REGULATOR.** This loop consists of the Pre-regulator and the Voltage Controlled Oscillator (VCO) shown in Figure 3-3. The VCO samples the voltage present across the series pass element and supplies pulsed timing information related to the load power requirement. These pulses are synchronized to the start of the line frequency cycle and are applied to the pre-regulator. The pre-regulator then initiates line current flow to the high voltage supply in only the amount necessary to meet the actual load requirement, thereby improving the efficiency of the instrument.

3-19. **MAIN REGULATOR LOOP.** The main regulator loop consists of a Reference Supply and Ladder Network, a Control Amplifier, the Series Pass Element, and a High Voltage Power Supply. The configuration is shown in

Figure 3-3 and is redrawn in bridge form for explanation in the same illustration.

3-20. The reference supply/ladder network and  $R_{SOURCE}$  form one side of the bridge, while the series pass element/high voltage supply and  $R_{RANGE}$  form the other side. What the operator is doing when he dials an output voltage is to vary the Ladder Network which effectively produces a variable  $E_{REFERENCE}$ . The current from  $E_{REFERENCE}$  is determined by the Ladder and the effective voltage of  $E_{REF}$ . This current passes through  $R_{RANGE}$  developing a voltage across it which is equal to the dialed output voltage. When the voltage across  $R_{SOURCE}$  equals  $E_{REF}$ , and the voltage across  $E_{RANGE}$  equals  $E_{OUT}$ , a state of balance exists across the bridge, and there is zero potential across the inputs to the amplifier. When a new output voltage is dialed into the instrument, a state of imbalance will momentarily exist because  $E_{OUT}$  will no longer be equal to the voltage across  $R_{RANGE}$ . If, for example, the instrument is operating at 100 volts and is subsequently dialed to 500 volts, a positive error voltage will appear at the summing junction and at the input to the amplifier. This amplified positive error voltage (the control amplifier is non-inverting) is applied to the series pass element causing it to conduct harder and resulting in a lower voltage drop across it. Through the action of the series pass and the pre-regulator (mentioned later), the output voltage will rise until it equals the voltage across  $R_{RANGE}$ , or until the bridge is again balanced. The gain of the control amplifier is very high and provides the bulk of the regulation.

3-21. At the same time the control amplifier is causing the series pass element to increase in conduction, or, in other words, producing a lower voltage drop across the series pass, the VCO is sampling  $E_{SERIES PASS}$  and affecting the rest of the pre-regulator loop to increase the output of the high voltage supply.

### 3-22. Current Mode

3-23. **PRE-REGULATOR LOOP.** Operation of the pre-regulator loop is essentially the same in current mode as it is in voltage mode. The voltage across the series pass element is sampled by the VCO which causes the pre-regulator to supply power to the high voltage supply in the amount necessary to meet load requirements. A simplified block diagram of this mode is shown in Figure 3-4.

3-24. **MAIN REGULATOR LOOP.** The main regulator loop, like the pre-regulator loop, operates essentially the same in the current mode as in the voltage mode. The only difference is that the loop acts to maintain a constant vol-

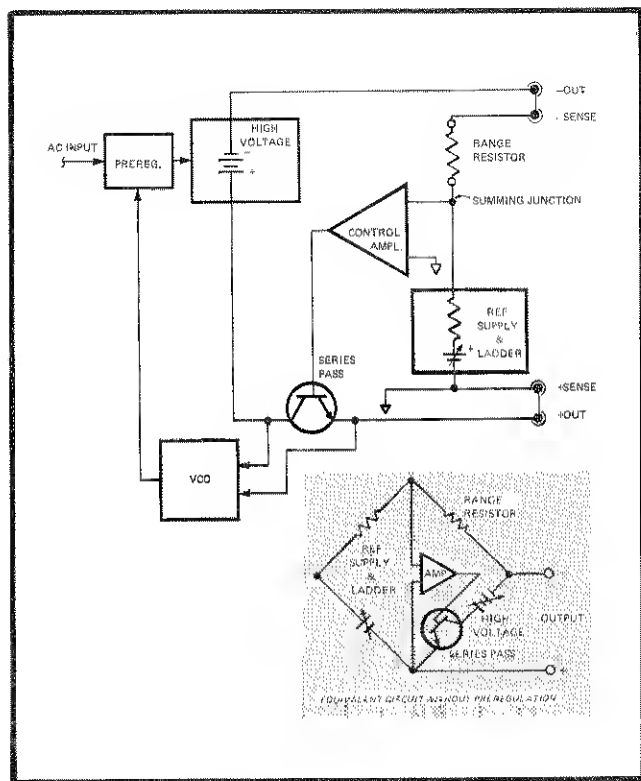


Figure 3-3. VOLTAGE MODE (SIMPLIFIED)

tage across the current shunt resistor (a precision resistor network) to ensure that a constant current is available at the output terminals. The action of the series pass element and control amplifier maintains the output current at whatever level is specified by the conditions of RANGE and the reference supply/ladder network.

### 3-25. GENERAL CIRCUIT ANALYSIS

3-26. This description relates primarily to the system block diagram found at the rear of the manual, Figure 8-1, and discusses the interaction of the major circuits. Some of the circuits mentioned are not represented on the block diagram, but are included to maintain continuity in the discussion.

3-27. The basic reference voltage for the instrument is the 10 volt reference supply. The supply employs a selected reference amplifier to ensure that the output reference voltage is highly stable with respect to time and temperature. The reference supply output is applied to the input of a seven deck resistive ladder network. This ladder is controlled by the seven front panel decade switches in the local mode, and by a 28 line 8-4-2-1 binary coded decimal (BCD) input in the REMOTE mode. The resulting voltage at the summing junction is applied to the input of the control amplifier, which consists of the chopper amplifier and differential amplifier. The function of the control amplifier is to control conduction of the series pass so that the resulting voltage at the summing junction approaches zero. The chopper amplifies all frequencies from dc to approximately 30 Hz; the differential amplifier is used principally for frequencies from 30 Hz to approximately 200 kHz and has a dc path for signals coming from the chopper.

3-28. The current limiter, together with the control amplifier and series pass, forms a servo loop which limits instrument output current at a present value. The current

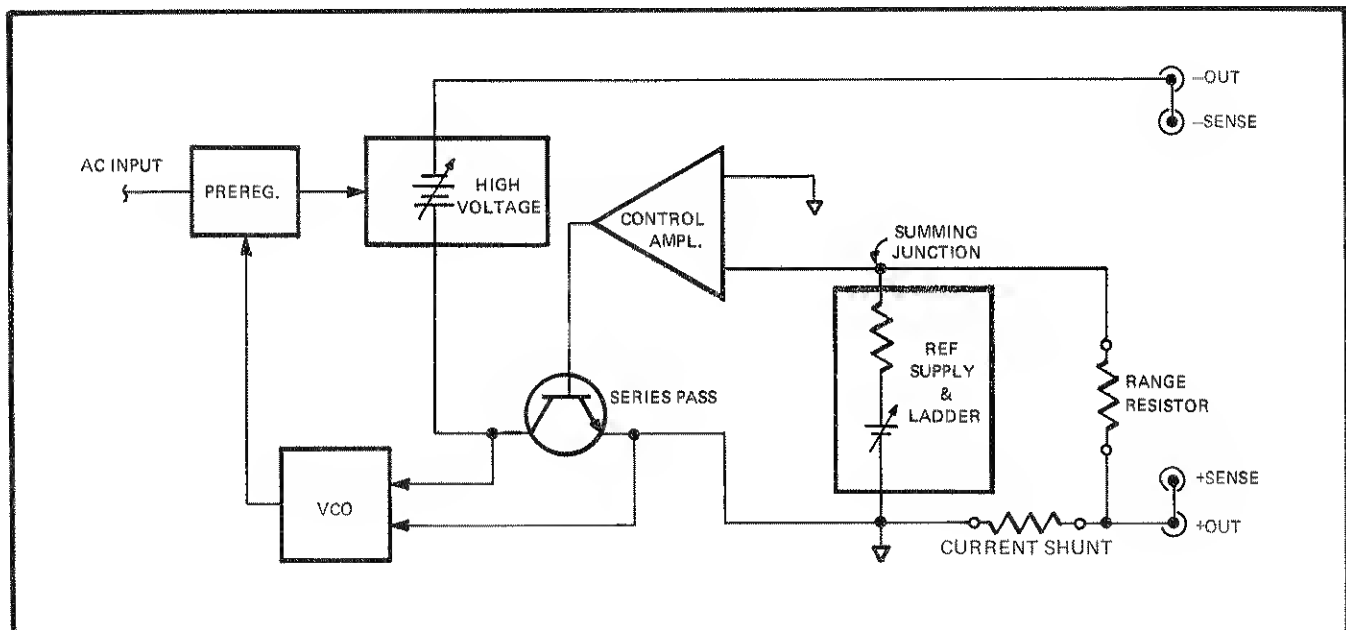


Figure 3-4. CONSTANT CURRENT MODE (SIMPLIFIED)

limiter continuously monitors output current and compares it to the setting of the CURRENT LIMIT control. When the voltage across the current sensing resistor exceeds the reference voltage set by the CURRENT LIMIT control, the limiter is activated. A portion of the current flowing from the reference supply into the summing junction is then bypassed, and the output current is limited or clamped to the preset value.

3-29. The series pass driver performs two functions: It amplifies control signals sufficiently to drive the series pass, and it disables the output in the event of an over-voltage or catastrophic over-current condition. When the voltage across the current sensing resistor exceeds a pre-determined value, the trip circuitry acts to de-energize relays A5A2K1 and A5A2K2 which removes ac power from the high voltage transformer primary. The voltage trip circuit is activated whenever the output voltage exceeds the selected trip voltage set by the VOLTAGE TRIP VERNIER. Again A5A2K1 and A5A2K2 are de-energized and the instrument is tripped to standby. The instrument is reset by first pressing the STDBY/RESET switch to de-energize A4K5 and then the OPR switch.

3-30. The series pass regulates instrument output current in response to control signals from the series pass driver. The series pass is actually eight transistors connected in series, an arrangement which provides the regulated high voltage capability. The series pass assembly also contains a voltage controlled oscillator (VCO) which provides a pulsed timing signal to the pre-regulator. The pre-regulator increases the efficiency of the instrument by regulating the input to the high voltage power supply. It utilizes voltage level information from the VCO to provide full-wave phase control of the input line voltage of the high voltage transformer. Thus, the power supplied by the high voltage transformer is controlled to provide only that amount necessary for load requirements.

3-31. The high voltage power supply is connected as a full-wave bridge rectifier, obtaining its input from the pre-regulator and supplying dc voltages to the series pass regulators. Contained on the high voltage assembly is a rate limiter for the automatic crowbar which prevents excessive crowbar activation, thereby providing protection for the series pass transistors. See paragraphs 3-67, 3-70 and 3-74.

3-32. The function of the automatic crowbar circuitry is to quickly discharge the high voltage filter capacitors when down-ranging the instrument. This circuit also provides protection for the instrument during abnormal load conditions, such as short-circuited output. A second crowbar

circuit, which is manually operated, is connected across the output terminals. It is used to limit compliance voltage while changing loads.

3-33. Operating voltages for the instrument are provided by the low voltage power supplies. The +25 volt and -15 volt supplies provide operating voltages for the +10 volt reference, chopper amplifier, and differential amplifier. A separate -25 volt dc supply furnishes operating voltages for all decade control relays. Operating voltages for the series pass driver are provided by a  $\pm 35$  volt supply located on the current limiter assembly. A -5 volt supply provides the program supply voltage.

3-34. The 50 program input/output (I/O) lines provide remote control of all front panel control functions and remote indication of instrument power condition and voltage trip/current limit operation. Mode, standby/operate, polarity, manual crowbar, and voltage/current range input lines terminate in a relay driver, which supplies the driving current for the selected relay. Output voltage level is controlled by a 28-line 8-4-2-1 BCD input. The front panel controls are connected in parallel with the program I/O lines, and the same circuits are activated in either remote or local operation. The selection of remote or local operation is made only at the front panel. When the OPR switch is pressed, front panel controls are enabled; when the REMOTE switch is pressed, instrument control is switched to the programmed input at J8.

3-35. Mode input commands are applied through the relay driver to relays A4K3 and A4K6. These relays change the instrument circuitry to provide either voltage or constant current operation. Together with the range relays A4K1 and A4K2, they select the appropriate voltage range resistor, current shunt, and chopper amplifier zero adjust control.

3-36. The standby/operate input is applied through the relay driver to relay A4K5. This relay controls the operation of relay A5A2K2, which in turn, controls relay A5A2K1. When operated, A5A2K1 connects main power to the pre-regulator. The remote polarity input is applied through the relay driver to relay A4K4. Upon command, A4K4 reverses the output voltage polarity at the front and rear terminals. The manual crowbar input operates relay A6K2. When activated, this relay shorts the output terminals through a 5 ohm resistor.

3-37. The 28-line output level input is applied to the seven-deck resistive ladder network and a set of relay switches, which are used to connect the reference voltage

to the proper terminal of the network as a function of each digital input bit.

3-38. The 5-line current limit input consists of a 4-bit BCD input which is applied to the remote current limit circuit, and a single local/remote line which is applied through a relay driver to A3K1 and A3K6. Upon remote command, A3K1 closes and selects the current limit ladder. The circuit then performs the current limit adjustment in accordance with the BCD input. The voltage limit circuitry is arranged in the same way. The local/remote input operates relay A3K6 which selects the remote voltage limit ladder. Again, the BCD input controls the decoder which accomplishes the adjustment function.

### 3-39. CIRCUIT DESCRIPTIONS

3-40. The following paragraphs describe in detail the operation of each circuit. The information is grouped according to individual assemblies found in the Model 3330B. To find the description of a particular circuit, first determine the name of the assembly that the circuit is located on and proceed from there. For example, the VCO circuit is located on the Series Pass assembly A4A5.

#### 3-41. Main Mother Board (A4)

3-42. Functioning as the parent assembly for assemblies A4A1 through A4A17, the Main Mother Board interconnects all the assemblies found on it and distributes signal paths to appropriate sections of the instrument. Individual circuit descriptions for A4A1 through A4A17 are provided in the following paragraphs.

3-43. Components mounted on the A4 board consist primarily of diodes and relays. Diodes CR1 through CR28 are associated with the ladder assemblies. Relays K3 and K6 form part of the mode selection circuitry. K2 is energized when the instrument is in the 1000 volt range. K1 is energized in the 100 volt range and de-energized in the 10 volt range. Relay K5 is the Standby/Operate relay, and K4 is the Polarity relay.

#### 3-44. +10 Volt Reference Supply (A4A1)

3-45. The +10 Volt Reference Supply produces an extremely stable reference voltage upon which the instrument's stability is based. Range zero adjustments and a resistor for the current mode are also located in this assembly.

3-46. **10 VOLT REFERENCE SUPPLY.** This is a voltage regulated power supply consisting of a stable reference amplifier, a differential comparator amplifier, and a series regulator. Reference amplifier IC2 contains a matched zener reference and amplifier elements to produce an extremely stable voltage with respect to time and temperature. Voltage variations at the regulator sense line (terminal 14) are developed across the voltage divider R10 through R13 and R2 and are applied to the other input of IC2. Any difference between the sense terminal voltage and the reference voltage is amplified by IC2 and IC1 and used to control the conduction of the series regulator Q1 and Q2, which establishes a +10 volt dc reference voltage at terminal 15. Variable resistor R10 provides adjustment of the regulated output voltage.

3-47. **RANGE ZERO AND CURRENT SHUNT.** The voltage divider of R16 through R21 allow zero adjustments in the voltage mode of operation. Resistor R22 is used in the current mode of operation.

#### 3-48. Chopper Amplifier (A4A2)

3-49. The Chopper Amplifier compares low frequency and dc control signals from the Ladder summing junction to the +SENSE terminal voltage and amplifies any difference. The Chopper Amplifier circuitry consists of an input filter, a MOSFET chopper, an operational amplifier, a synchronous demodulator, an output filter, and a multivibrator.

3-50. Low frequency and dc control signals at terminal 6 are passed through the input filter C2, R1, and C3 to reject frequencies above 30 Hz. The MOSFET chopper Q1 modulates the signal appearing at the junction of its drain and R2. C4 couples the resultant to the gate of JFET Q2. The output signal at the drain of Q2 is then amplified by the operational amplifier IC1, which has a gain of approximately 420. The paraphase amplifier Q3 amplifies the output of IC1 and provides two equal amplitude, but 180° out-of-phase signals. The collector signal of Q3 is coupled by C16 to the shunt demodulator Q4. The resulting demodulated signal appearing at the junction of C17 and R24 is filtered by R24, R26 and C18, leaving only the amplified dc and low frequency signals. The emitter signal of Q3 is applied through C14, R21, C15, R25, R23, and C22 to C18, where it is used to cancel any chopper ripple at 215 Hz.

3-51. The 215 Hz multivibrator is formed by Q6, Q7 and associated timing networks, in addition to a driver Q5. Variable resistor R43 adjusts the level of the signal applied to the driver Q5, and subsequently the output

signal applied to the gate of Q1. The collector signal of Q5 is applied to the drain of Q1 to compensate for spikes coupled between the gate and drain. Variable resistor R34 provides adjustment of the compensation signal. An output signal at the collector of Q7 is applied to the base of Q4, which synchronously demodulates the Chopper Amplifier output.

### 3-52. Differential Amplifier (A4A3)

3-53. The Differential Amplifier provides a control signal to the Series Pass Driver. Part of the current limit circuitry is also located in this assembly. The differential amplifier consists of Q2 through Q11, and the current limit circuitry consists of Q1, Q12, CR10 through CR12, and R7 through R10. A restraining circuit of Q13, and Q14, and associated circuitry, prevents the chopper Amplifier from saturating in the standby mode.

3-54. DIFFERENTIAL AMPLIFIER. Input control signals from the A4A10 through A4A16 Ladder summing junction are applied to terminal 5 for amplification by the differential amplifier of Q2 through Q10. High frequency input signals are coupled through C1 to one input of the differential amplifier. Low frequency and dc control signals are applied through R21 to terminal 6, where they are amplified by the A4A2 Chopper Amplifier. Over-voltage protection for the differential amplifier and Chopper Amplifier inputs is provided by CR2 through CR9 and associated components. The amplified control signals from the Chopper Amplifier are applied to terminal 3 as the other input of the differential amplifier. The resulting output at the collector of Q9 is applied to the emitter follower Q11, which provides a low impedance drive signal required by the A4A4 Series Pass Driver at terminal 1. Transistor Q8 is a current source for one stage of the amplifier and provides common mode rejection at the input to the amplifier.

3-55. CURRENT LIMIT CIRCUITRY. The current limit circuitry consisting of Q1, Q12, CR10 through CR12, and R7 through R10 provide a means of bypassing Ladder current during a current limit condition. Transistor Q1 receives base and emitter operating voltages from the A4A7 Current Limiter and is normally cut-off. However, if the output current of the instrument exceeds a preset value established by the CURRENT LIMIT control, Q1 is driven into conduction by a corresponding drop in emitter voltage and turns on transistor diode Q12. Conduction of these transistors shunts the Ladder current through the range resistor R9, thus limiting the control signal applied to the A4A4 Series Pass Driver and the output current of the instrument.

3-56. RESTRAINING CIRCUIT. The circuitry of Q13 and Q14 ensures that the Differential Amplifier is provided with a dynamic load during a standby condition to keep the output of the amplifier relatively constant. This also maintains fast response during turn-on and range changes. The emitter voltage of Q14 is derived from the emitter of Q11, while the base voltage of Q14 is derived from the voltage divider of R33 and R34. The collector of Q14, whose conduction depends primarily on its emitter voltage, supplies base drive to Q13. The output of Q13 drives diode-connected Q12, controlling the current appearing in the summing junction. In this manner, the loop is completed and the output of the Differential amplifier will remain nearly constant, thus preventing the Chopper from going into saturation.

### 3-57. Series Pass Driver (A4A4)

3-58. The Series Pass Driver applies amplified control signals to the A4A5 Series Pass assembly. Additional circuits found on the assembly are the overcurrent/voltage trip circuit and the front panel meter multiplier resistors. A three-stage amplifier composed of Q5 through Q7 forms the series pass driver. The overcurrent/voltage trip circuitry consists of Q1 through Q4 and Q8. The meter multipliers are R1 through R6.

3-59. SERIES PASS DRIVER. The series pass driver of Q5 through Q7 amplifies the input regulation control signal at terminal 1 sufficiently to drive the A4A5 series-pass transistor Q8. The common-base configuration of Q7 provides isolation of the input circuitry and the required voltage gain of the control signal. The common-collector stages of Q5 and Q6 provide sufficient current gain of the drive signal applied out terminal 4.

3-60. OVERCURRENT/VOLTAGE TRIP. The over-current/voltage trip circuitry, through relay A5A2K2, removes ac power from the high voltage transformer whenever a catastrophic overcurrent or voltage trip occurs. Transistor Q3 is a current source for the solenoids of this relay and produces a -30 volt dc operating voltage at terminal 10. Transistors Q1 and Q2 activate the voltage trip feature. Transistors Q4 and Q2 activate the over-current trip feature. Resistors R22 and R29 are the sensing resistor for the overcurrent trip feature. Transistor Q8 is the driver amplifier for the OPR indicator lamp.

3-61. The voltage trip feature is activated when the output of the instrument exceeds the level established by the VOLTAGE TRIP controls, or when triggered by the rate limiter. (Paragraph 3-74). Transistor Q1 receives

its base voltage from the wiper of the VOLTAGE TRIP VERNIER control or Ladder. When the base voltage, which is proportional to the output voltage of the instrument, exceeds the established level at the base of Q1, the transistor conducts and biases Q2 into saturation. The conduction of Q2 clamps the voltage at terminal 10 to nearly zero volts and de-energizes the associated relays. This action trips the instrument to the STANDBY mode. Transistor Q8 is also turned off by a corresponding decrease in negative base voltage, and the OPR lamp is extinguished. The instrument is returned to the OPR mode by first selecting the STDBY/RESET mode, which turns off Q2 by applying a circuit common to terminal 10 through the contacts of A4K5, and then selecting the OPR mode.

3-62. The overcurrent trip feature is a protective circuit that functions in the event of a current limit malfunction. When the current through the sensing resistors of R22 and R29 exceeds 200 milliamperes, Q4 conducts and biases Q2 into saturation, which activates the trip circuit discussed in the preceding paragraph.

3-63. METER MULTIPLIERS. Resistors R1 through R6 provide a current through the front panel meter that is proportional to either the output voltage or current of the instrument. When the METER READING VOLTAGE switch is pressed, R3 through R6 and A4R1 through R3 are connected to the meter and produce a reading proportional to the output voltage of the instrument. Variable resistor R5 allows calibration of the voltage reading. When the METER READING CURRENT switch is pressed, R1 and R2 are connected to the meter and produce a reading proportional to the output current of the instrument. Variable resistor R2 allows calibration of the current reading.

### 3-64. Series Pass (A4A5)

3-65. The Series Pass contains the series-pass transistors used to control the output current or voltage from the instrument. Additional circuitry consists of the pre-regulator VCO used to control the amount of voltage across the series pass transistors, and an automatic "crowbar" driver used to limit the maximum voltage across the series-pass elements. A +150 volt power supply is also included to provide operating voltages for the series-pass and VCO circuitry. The +150 volt power supply consists of the bridge rectifier CR1 through CR4, and the series pass elements are Q1 through Q8. The VCO consists of the relaxation oscillator Q9 and the associated timing networks. Transistor Q10 is the automatic "crowbar" driver.

3-66. +150 VOLT POWER SUPPLY. AC voltage at terminals 8 and 9 is rectified by diodes CR1 through CR4 to produce an unfiltered positive voltage. This voltage is isolated by CR5 and filtered by C2 to provide a +150 volt dc operating voltage for the series pass transistors. The voltage divider of R1 through R3 and zener diode CR6 produces a clipped full-wave rectified six volt synchronizing signal for the VCO, Q9.

3-67. SERIES PASS TRANSISTORS AND AUTOMATIC CROWBAR. The series-pass transistor of Q1 through Q7 are normally saturated, and transistor Q8 is absorbing the total voltage required to establish the output of the instrument. However, when the output level or load is changed and the voltage across Q8 exceeds 150 volts, Q1 through Q7 absorb the additional voltage. The pre-regulator circuitry then reduces the output of the high voltage supply and the voltage across the series pass transistors. As soon as the voltage drop across Q8 decreases below 150 volts, Q1 through Q7 again saturate, and Q8 absorbs the total regulation voltage. Load or output changes that increase the voltage across the series pass transistors to above 225 volts result in the conduction of the "crowbar" driver, Q10. Conduction of Q10 energizes relay K1 in the A4A6 High Voltage assembly, which places a load across the high voltage rectifier. This action limits the voltage across the series pass transistors and provides a quick discharge path for the high voltage filter capacitors.

3-68. PREREGULATOR VCO. Unijunction transistor Q9 and associated timing elements comprise a voltage-controlled oscillator which furnishes a turn-off pulse to the pre-regulator. A clipped, six volt pulse, synchronous with the 60 Hz line, is applied to base 2 of Q9 (see Figure 3-5). The potential at the emitter of Q9 depends upon the charge on capacitors C4 and C5. The charge on C5 depends upon the voltage across the series pass control transistor Q8. When the charge on C4 and C5 equals a critical level, determined by the bias on Q9, Q9 will conduct, delivering a pulse of current through transformer T1 to the pre-regulator. The oscillator will be enabled only during interval  $t_1$  and the point at which oscillation will occur is determined by the charge on C5. If the Charge across C5 increases, the initial output pulse of the oscillator will occur earlier in each half cycle. During each half cycle, the initial pulse from the oscillator will switch the pre-regulator off to control the amount of line power supplied to the high voltage transformer. Thus, if the voltage across Q8 increases, the pre-regulator is switched off earlier in each half cycle. This, in turn, reduces the voltage across Q8 to the proper working value.

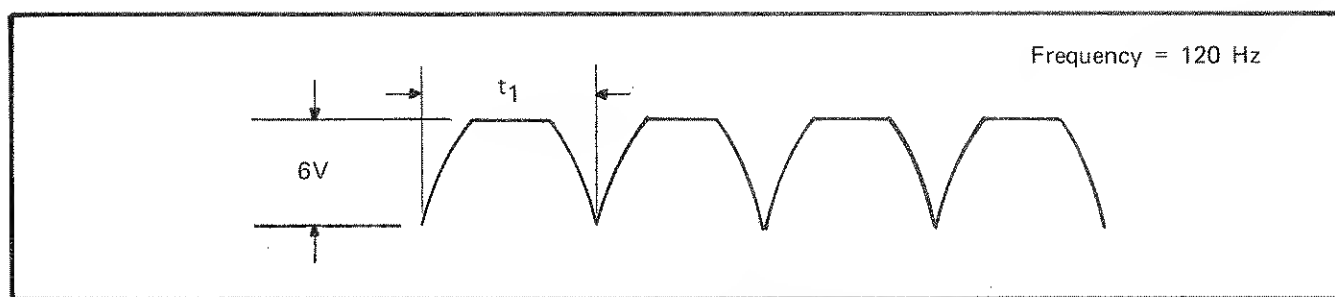


Figure 3-5. VCO OPERATING VOLTAGE

### 3-69. High Voltage Power Supply (A4A6)

3-70. The High Voltage Power Supply produces the required voltage necessary to obtain the pre-selected output. Additional circuitry consisting of a sink supply and a portion of the automatic "crowbar" circuitry is also included and allows rapid downranging of the instrument. The automatic "crowbar" circuit also prevents damaging of the series pass elements if the output terminals are shorted or an overload occurs. The high voltage power supply consists of the bridge rectifier CR1 through CR4. The sink supply is composed of the voltage doubler CR5 through CR8, and the automatic "crowbar" circuit consists of K1 and R7 with the rate limiter of Q1 thru Q4 acting to limit the number of times the crowbar may be activated at a given time.

3-71. HIGH VOLTAGE POWER SUPPLY. AC input voltage from the pre-regulator at terminals 15 and 16 is rectified by CR1 through CR4 to provide high level operating voltage for the instrument. Resistors A4R6 through A4R8 and capacitors A4C5 through C7 filter the resulting output appearing on terminal 5.

3-72. SINK SUPPLY. AC input voltage at terminals 1 and 2 is rectified and filtered by CR5 through CR8, C1, C2, R4, and R5. The resulting -700 volts output at terminal 12 is applied to the A4A5 Series Pass assembly and ensures a minimum current through the series-pass element when the instrument is downranged.

3-73. AUTOMATIC CROWBAR. Relay K1 and the resistor R7 are part of the automatic "crowbar" circuit used to provide a quick discharge path of the filter capacitors contained within the instrument. When an over-voltage condition across the series pass elements is detected, A4A5Q10 will conduct and energize K1. The contacts of K1 place R7 in parallel with the high voltage power supply which provides a discharge path for the filter capacitors.

3-74. RATE LIMITER. The rate limiter, in conjunction with the automatic crowbar, protects the series pass transistors. If the automatic crowbar activates more often than the times given in Figure 1-1 of Section I, the rate limiter relay K2 will supply -35 v to the voltage trip circuitry, placing the instrument in the voltage trip mode. Q1 thru Q4, CR12 thru CR19, R3, R9 thru R14, C4 thru C6, and K2 comprise the rate limiter circuitry. When the crowbar activates due to excessive voltage across the series pass, a voltage develops across R3 charging C5 directly and charging C4 through R9. If there is excessive crowbar action, C4 will charge sufficiently to turn on Q1 and Q2, energizing K2. If the crowbar rate is not excessive, the charge on C4 will not become great enough to turn on Q1 and Q2. Meanwhile, as a result of the crowbar action, C5 becomes charged; when the charge is high enough, Q4 conducts, turning off Q3. Some time later, it will discharge, turning off Q4 and allowing Q3 to conduct. When Q3 turns on, it discharges C4, and the rate limiter is reset. However, the 3330B must be manually reset.

### 3-75. Current Limiter (A4A7)

3-76. The Current Limiter contains two separate plus and minus 35 volt dc power supplies and part of the current limit circuitry. The  $\pm 35$  volt power supply is a bridge supply with rectifiers CR1 through CR4 and the regulators Q1 and Q2. The current limit circuitry consists of a three-stage amplifier, Q3 through Q5, and the I LIMIT/V TRIP drivers Q6 and Q7.

3-77.  $\pm 35$  VOLT DC POWER SUPPLIES. The ac input voltage applied to terminals 7 and 9 is rectified and filtered by CR1 through CR4, R1, C1, R4, and C4. Positive unregulated voltage is applied to Q1, and negative unregulated voltage is applied to Q2. Zener diodes CR5 and CR7 establish a reference voltage at the base of Q1 and Q2. The conduction of Q1 and Q2 produces  $\pm 35$  volt dc output voltages available at terminals 1 and 3. A -3.9 volt dc output at terminal 15 is developed by CR6 and R6 for use as a bias voltage in the A4A3 Differential Amplifier.



The unregulated negative output is also applied through R8 and R26 to terminal 6 for use in the A3 assembly indicator lamps.

**3-78. CURRENT LIMIT CIRCUITRY.** The current limit circuitry receives a dc control voltage at terminal 10 which is proportional to the output current of the instrument. Diode CR12 applies this signal to the base of Q5. The emitter of Q5 is connected through R21 to terminal 11, which receives a control voltage from the wiper of the CURRENT LIMIT VERNIER control or Ladder. Variable resistors R23 and R24 are also part of this circuit and allow calibration of the CURRENT LIMIT LO and HI settings. When the output current of the instrument attempts to exceed the value preset with the CURRENT LIMIT control, Q5 is driven into conduction by the increase in voltage at terminal 10, which drives Q4 and Q3 into conduction. This action bypasses a portion of the Ladder current through the A4A3 Differential Amplifier range resistor connected to terminal 16, and thereby limits the output current of the instrument. The regenerative pair of Q6 and Q7 are also driven into conduction at this time and supply a drive current to the A3 I Limit/V Trip lamp which is also illuminated on the STDBY/RESET or VOLTAGE TRIP mode by a zero volt control signal at terminal 5. This input also brings Q3, Q4, Q6 and Q7 into conduction.

### **3-79. +25 and -15 Volt Power Supply (A4A8)**

**3-80.** The +25 and -15 Volt Power Supply consists of two separate low-ripple power supplies used to produce operating voltages for the instrument. The +25 volt power supply is composed of a bridge rectifier CR1 through CR4 and the regulator Q2 through Q6. The -15 volt power supply consists of a bridge rectifier CR7 through CR10 and the regulator Q7 through Q9. Transistor Q1 and associated components are not used in this instrument.

**3-81. +25 VOLT POWER SUPPLY.** AC voltage at terminals 13 and 14 is rectified and filtered by CR1 through CR4, C2, R4, and C3. Transistor Q2 is a constant current source for the regulator consisting of Q3 through Q6. The differential comparator amplifier of Q5 and Q6 receives a reference voltage at the base of Q6 derived from zener diode CR6. Variations at the +25 volt output (terminal 10) are developed across the voltage divider of R8 through R10 and are applied to the base of Q5. Any difference between the base voltages of Q5 and Q6 is amplified and used to control the conduction of the series-pass driver Q3. Conduction of Q3 controls the conduction of the series-pass regulator transistor Q4, which establishes a low-ripple +25 volt dc output at terminal 10. Variable resistor R9 allows adjustment of the regulator output.

**3-82. -15 VOLT POWER SUPPLY.** AC voltage at terminals 1 and 6 is rectified and filtered by CR7 through CR10, R14, and C8 to produce a negative operating voltage for the regulator of Q7 through Q9. A voltage divider comprised of R18 and R19 references the base of Q9 to a potential dependent on the +25 and -15 volt output. Variations in the output are amplified by Q9 and used to control the conduction of Q8. The conduction of Q8 controls the series-pass regulator Q7, which establishes a low-ripple -15 volt dc output at terminals 3 and 9.

### **3-83. Relay Driver (A4A9)**

**3-84.** The Relay Driver activates the various relays within the instrument on commands from the A3 assembly. The relay drivers Q1, Q3, Q5, and Q7 are identical PNP switches used to activate relays. Transistors Q4, Q10, Q11 and Q12 are used to invoke the STDBY/RESET mode whenever a mode or polarity change occurs. A Logic "1" (0 to +0.5 volts) will turn the relay drivers on, and a Logic "0" (+4.5 to +20 volts) will turn them off.

**3-84. RELAY DRIVERS.** Relay drivers Q1, Q3, Q5, and Q7 are identical PNP switches. Each transistor receives -25 volts at its collector derived from the associated relay. Base voltage is dependent on the input logic signal from the A3 assembly. Zener diodes located in the collector circuit protect the transistors from the induced voltages developed by the relay solenoids. The drivers consisting of Q2, Q8 and Q6, Q9 provide current for relay operation. Circuitry for these drivers is essentially the same as the other drivers, with the exception of the additional base circuitry used to invoke the STDBY/RESET mode.

**3-86. STDBY/RESET MODE.** When changing a program between the voltage or current mode, it is necessary to temporarily place the instrument in standby to prevent uncontrolled voltages from appearing on the output terminals. This is accomplished by circuitry located on the relay driver assembly. When the negative or low input is applied to the base of Q9 (current mode command), it is also applied to a differentiator consisting of C6 and R30. The negative differentiator output is coupled through diode CR12 to the base of Q11, turning it on. Q12 turns on at the time that Q11 does, and stays on until C7 discharges through R26 to a value below 0.6 volts, a period of approximately 100 milliseconds. In the interval that Q12 is on, the base of Q3 is effectively connected to ground, which de-energizes relay A4K5 and places the instrument in standby. When the positive or high input is applied to the base of Q9 (voltage mode command), it is also applied to the base of Q4. The signal is inverted in Q4, differentiated by C5 and R28, and applied to Q11.



Again, Q11 and Q12 together with Q3 act to place the instrument in standby for 100 milliseconds. The momentary standby function is also invoked by application of a polarity change command. A separate inverter Q10 together with associated differentiator circuits provide the negative trigger to Q11.

### 3-87. Ladders (A4A10 through A4A16)

3-88. There are seven Ladders contained in the instrument. Each Ladder consists essentially of the same circuitry with the only difference being the tolerance of the divider components. The Ladder circuitry consists of relay driver/decoders and a ladder network.

3-89. RELAY DRIVER/DECODERS. Relay Drivers Q1 through Q4 are PNP switches. A Logic "1" (0 to +0.5 volts) will turn the drivers on, and Logic "0" (+4.5 to 20 volts) will turn them off. Each transistor receives a -25 volt dc collector voltage through the associated relay of K1 through K4. Base bias voltage is dependent upon the input logic signal from the A3 assembly. Diodes CR5 and CR6 convert the 8-4-2-1 coded inputs to a 4-4-2-1 code. This conversion is necessary to limit the maximum digital command to a four digital word of eleven which corresponds to the maximum decade range.

3-90. LADDER. Each deck of the seven ladder decks performs an identical function. The relative position of the decks, with respect to the summing junction, determines the significance of that deck's contribution to the ladder output. For example, Ladder no. 1, which is nearest the junction, determines the most significant portion of the output, and Ladder no. 7, which is farthest from the junction, determines the least significant portion. Although the circuit arrangement of each ladder is the same, the individual assemblies are not interchangeable, because component tolerance are different.

3-91. Ladder network R1 through R10, reed relay switches K1 through K4, and switch drivers Q1 through Q4 comprise a four-bit, weighted-resistor, digital-to-analog decoder. The analog output of the decoder is weighted in terms of elevenths of the reference voltage (+10 volts) so that it can be programmed by input digital words 1 through 11. The ladder network functions as a voltage divider, where resistors R3 through R10 are, in various combinations, connected in series with R1 and R2, which are the output resistors. Assume, for example, the four-bit digital word 0101, representing 5, is present at the decoder input. The first and third bits, present at pins 16 and 14 respectively, turn on drivers Q2 and Q4 and, through them, relays K2 and K4, while the second and

fourth bits, present at pins 15 and 13, bias drivers Q3 and Q1 off. With K2 and K4 energized, +10 volts is applied to R5 and R9. The parallel combination of R5, R6 and R9, R10 in series with R1, R2 provide an output that is five-elevenths of the available decoder output. This decoder deck together with the other decoder decks produces a combined output which corresponds to the 28-word BCD input. An important characteristic of the ladder is that its output impedance is constant regardless of the reed switch positions, thereby presenting a constant load to the reference supply.

3-92. Referring to the simplified diagram of Figure 3-6, the operation of the Ladders can be more easily seen. The numerals "4", "4", "2", and "1" refer to the BCD commands, and the 1R, 2R, etc., refer to the relative weights of the associated Ladder segments. The value of 1R is 25K, so that 2R is 50K, etc. Selecting various combinations of "R" in each Ladder varies the current supplied to the Range resistors; this current is available in increments of 1/11 from each Ladder.

### 3-93. Range/Shunt Networks (A4A17)

3-94. The Range/Shunt Networks allow calibration of the various voltage/current ranges of the instrument. Variable resistors R21, R18, and R15 are used to calibrate the full-scale output on the corresponding 10, 100, and 1000 volt ranges. Variable resistors R1, R5, and R9 are used to calibrate the full-scale output on the corresponding 1, 10, and 100 milliampere ranges.

### 3-95. Rear Mother Board (A5)

3-96. The Rear Mother Board contains the A5A1 power supply assembly and the A5A2 Pre-regulator Assembly. Also located on the board are K1, the CURRENT LIMIT/VOLTAGE TRIP FLAG delay; K2, used in current limit and voltage trip conditions; and K3, the CURRENT LIMIT/VOLTAGE TRIP FLAG. A5T1 on this assembly couples the VCO pulses from the A4A5 Series Pass Assembly to the A5A2 Pre-regulator assembly.

### 3-97. -25 and -5 Volt Power Supply (A5A1)

3-98. The -25 and -5 Volt Power Supply consists of two separate low-ripple power supplies that produce the logic power and relay operating voltages for the instrument. The -25 volt power supply consists of a bridge rectifier CR1 through CR4, positive rectifier CR5 and CR6, the regulator Q1 through Q3, and the turn-on delay circuit Q4. The -5 volt power supply consists of a bridge rectifier CR7 through CR10 and the regulator Q5 through Q8.

3-99. **-25 VOLT POWER SUPPLY.** AC voltage at terminals 1 and 2 is rectified and filtered by CR1 through CR4 and C1 to provide a negative operating voltage for the regulator Q1 through Q3. Diodes CR5 and CR6 produce a positive operating voltage for the regulator. The comparator amplifier Q1 receives a reference voltage at its emitter derived from zener diode CR12. Variations at the -25 volt output (terminal 6) are developed across the voltage divider of R4 through R6 and applied to the base of Q1. Any difference between the base and emitter voltage of Q1 is amplified and used to control the conduction of the series pass regulator Q2. Conductions of Q2 controls the conduction of the series-pass transistor Q3, which establishes a low-ripple -25 volts dc output. Variable resistor R5 allows adjustment of the regulator output. The turn-on delay circuit consisting of C4, R7, CR13, Q4 and K1 prevents the -25 volt output from appearing at terminal 6 for approximately three seconds after initial turn-on.

3-100. **-5 VOLT POWER SUPPLY.** AC voltage at terminals 14 and 15 is rectified and filtered by CR7 through CR10 and C5 to produce a negative operating voltage for the regulator configuration of Q5 through Q8. Additional negative operating voltage is obtained from the -25 volt power supply through R8 and R10. The comparator amplifier Q7 receives a reference voltage at its emitter derived from zener diode CR11. Variations at the -5 volt output (terminal 16) are developed across the voltage divider of R11 and R12 and applied through R14 to the base of Q7. Any difference between the base and emitter reference voltage of Q7 is amplified and used to control the conduction of the series-pass regulator Q6. Transistor Q8 functions as a current limiter to prevent the output current from exceeding 300 ma. The conduction of Q6 controls the conduction of the series-pass transistor Q5, which establishes a low-ripple -5 volt dc output at terminal 16. Variable resistor R11 allows adjustment of the regulator output.

### 3-101. Pre-regulator (A5A2)

3-102. The Pre-regulator controls the ac power dissipated in the instrument by passing only enough power to the high voltage circuitry to meet the output load requirement. The Pre-regulator consists of the  $\pm V$  power supply CR1 through CR4, a relay power supply CR6 through CR9, pre-regulator drivers Q2 and Q4 through Q7, a pre-regulator bridge CR10 through CR13 and Q1, and current limiter Q3.

3-103.  **$\pm V$  POWER SUPPLY.** AC voltage at terminals 11 and 12 is rectified by CR1 through CR4 to provide unfiltered  $\pm V$  operating voltages. Diode CR5 provides isolation of a +10 volt filtered output.

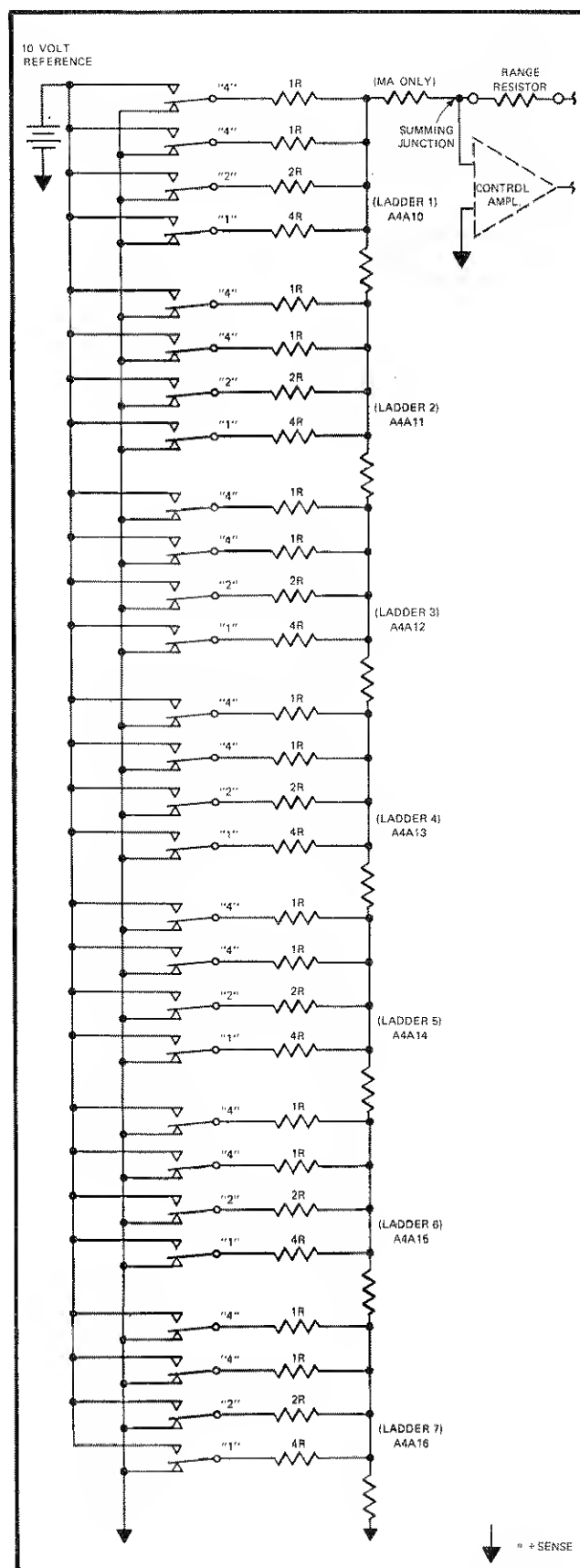


Figure 3-6. LADDER NETWORK -  
SIMPLIFIED VERSION

3-104. **RELAY OPERATION.** Operating voltage for relay K1, which applies ac voltage to the pre-regulator bridge, is produced by the bridge rectifier CR6 through CR9. Relay K2 is energized when the instrument is in operate. During an overcurrent or voltage trip condition, both relays de-energize and remove the ac input to the pre-regulator.

3-105. **PRE-REGULATOR DRIVERS.** The series of VCO pulses are coupled across A5T1 from the series pass assembly to the input of the pre-regulator. At the beginning of each 60 Hz half cycle, Q5 is turned on by the positive going +V voltage through R17 and L2. Conduction of Q5 saturates Q4, Q2, and Q1. Conduction of Q1 allows current to flow in the primary of the high voltage transformer. Sometime during each half cycle, the initial pulse from the VCO will trigger the regenerative pair (Q6 and Q7) into saturation. With Q6 and Q7 conducting, transistors Q5, Q4, and Q1 turn off and remain off as long as Q6 and Q7 are conducting. Transistors Q6 and Q7 remain conducting until the end of each half cycle. At this time, the current through them automatically drops below the regenerative value, due to the zero-crossing of the full-wave rectified 60 Hz sine wave voltage ( $-V$ ) at the emitter of Q7. Therefore, transistor Q1 is held off for the remainder of the half cycle, which corresponds to the period that the VCO is generating pulses. This limits the amount of power to the high voltage transformer and reduces the power dissipation requirements for the series pass transistors.

3-106. **PRE-REGULATOR BRIDGE.** The pre-regulator bridge of CR10 through CR13 and Q1 passes or attenuates the ac voltage applied to the high voltage transformer T1 in amounts determined by the Pre-regulator drivers. The bridge connected diodes of CR10 through CR13 provide an unidirectional current flow through the control element Q1. Positive alternations are passed by CR10 and CR13. Negative alternations are passed by CR11 and CR12. Whenever Q1 is turned-off, R5 and C6 provide a dynamic load for the bridge. Over-voltage protection for Q1 is provided by zener diode CR14. Overcurrent protection for Q1 is provided by R2 and the current limiter Q3. Essentially the bridge functions as a switch in the ac line. Refer to the simplified diagram and the stylized waveforms of Figure 3-7. The portion of the ac line waveform that passes to the High Voltage transformer is represented by the shaded portion of waveform 1. Waveform 2 represents the base drive to the bridge transistor. The pulses of waveform 3 are from the VCO. Note that the initial pulse turns off the base drive to the bridge transistor, and that the next zero crossing of the line waveform turns the base drive back on, resulting in current flow through the bridge. Only the first VCO pulse is used for turn-off.

3-107. **CURRENT LIMITER.** Maximum current through Q1 is limited to 17 amperes by the current limiter Q3. Normally, Q3 is cut-off; however, if the current through R2 in the pre-regulator bridge exceeds 17 amperes, Q3 conducts and turns on the regenerative pair of Q6 and Q7. Conduction of these transistors turns off Q2 and Q1, thus limiting the current through the pre-regulator bridge

### 3-108. Protection Circuitry

3-109. Instrument protection is afforded by several circuits; the over-voltage/over-current trip circuit, discussed with the series pass driver assembly in paragraph 3-60, the automatic and manual crowbar circuits, and the rate limiter (paragraph 3-74).

3-110. **CROWBAR CIRCUITS.** The automatic crowbar circuit consists of transistor Q10 in the series pass assembly, relay K1 on the high voltage assembly, and associated circuitry. When the voltage across the series pass element reaches approximately 225 volts, transistor Q10 conducts. Since relay K1 is in the collector circuit of Q10, the relay is energized, closing the contacts. With the K1 contacts closed, a discharge path is provided for the filter capacitors. The manual crowbar circuit consists of relay driver Q1 on

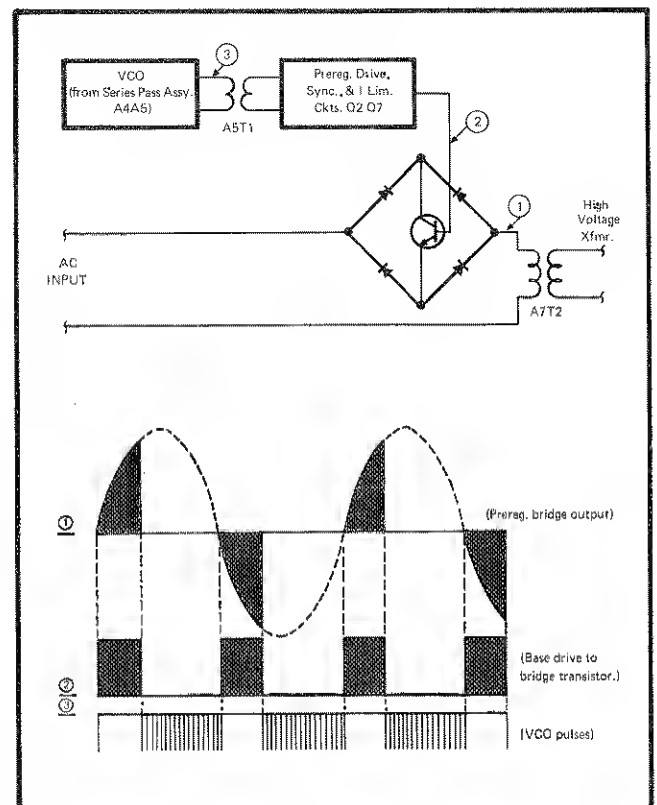


Figure 3-7. PREREGULATOR SIMPLIFIED DIAGRAM AND STYLIZED WAVEFORMS

the Relay Driver Assembly A4A9 and relay A6K2. The instrument output is connected to the normally open contacts of A6K2. When the front panel CROWBAR-OFF switch is depressed, the relay is de-energized and, consequently, has no effect. When the CROWBAR-ON switch is pressed, A6K2 is energized, through the relay driver, and resistor A6R1 is placed across the output terminals to quickly discharge the output capacitors.

### 3-111. Control Circuitry and Front Mother Board

3-112. The Control Circuitry for the instrument consists of four assemblies. The parent assembly is the (A3) Front Mother Board, which interconnects the (A3A1) Decade Switch assembly, the (A3A2) Switch Board, and the (A3A3) I Limit/V Trip assembly, and distributes the resulting control signals to the appropriate sections of the instrument. Programming inputs from the rear panel Remote connector, except for the operate, voltage trip range and vernier and current limit are parallel connected with the limit circuitry in the instrument. The Voltage Trip range is determined by the relay switching circuitry. The operate line is routed through the Front Mother Board in order for both local and remote modes of operation to be controlled by the inhibit circuitry which prevents the instrument from being turned on before being placed in standby.

3-113. FRONT MOTHER BOARD (A3). The Front Mother Board contains the ladder networks for the remote current limit and voltage trip vernier control features, a greater than 100 volt output detector, the status indicator lamps, and an inhibit circuit. The current limit ladder consists of Q5 through Q8, K2 through K5, and the remote selection circuit Q4 and K1. The voltage trip ladder consists of Q10 through Q13, K7 through K10, and the remote selection circuit Q9 and K6. Transistors Q1 through Q3 form the greater than 100 volt output detector, and the status indicator lamps consist of DS1 through DS10. The circuitry of K11 thru K13, Q17, and Q18 form the Voltage Trip range. Elements of the inhibit circuitry are IC1, Q15, and Q16.

3-114. The remote current limit ladder consists of relay drivers Q5 through Q8 and relays K2 through K5, a resistive ladder network of R17, R19, R21, and R23, and the remote selection circuit of Q4 and K1. The relay drivers are identical PNP switches which are turned on by a Logic "1" (0 to 0.5 volts) and turned off by a Logic "0" (+3.8 to 20 volts). Each transistor receives a -25 volt dc collector voltage through the associated relay which is connected to terminal 22. Base voltages are dependent on the input logic signals from the Remote connector. Diodes CR7

and CR8 convert the 8-4-2-1 coded input to 4-4-2-1 code, which limits the maximum digital command to a four digit word of eleven or 110 milliamperes. The resistive ladder network is selected in various combinations by relays K2 through K5 and divides the I limit resistance at terminal 19 into weighted terms of elevenths. The remote selection circuit of Q1 and K1 is activated upon the presence of a Logic "1" remote current limit command at terminal 21 and applies the ladder output to terminal 19. The current limit circuitry in the instrument receives this ladder output and limits the maximum output current to the level established by the coded inputs at terminals 43 through 46 of the Remote connector.

3-115. The remote voltage limit ladder employs relay drivers Q10 through Q13, relays K7 through K10, and the resistive ladder network of R26, R28, R30, and R32. The remote selection circuit for this network is Q9 and K6. Operation of the voltage limit ladder is essentially the same as that of the current limit ladder. Collector voltage for the relay drivers is obtained from the -25 volt source in the same manner described for the current limit ladder. CR9 and CR10 perform the 8-4-2-1 to 4-4-2-1 decoding. The ladder output appears at the remote contact of K6 and is coupled through R40 to the base of emitter follower Q14. The output is developed across R41 and appears on terminal 92.

3-116. The Voltage Trip Range circuitry is composed of K11 thru K13 and associated elements. Relay K13 is a "Local-Remote" relay for this circuit and is energized by Q9. With pins 3 and 4 held at Logic "0", the 10 volt trip range is activated. When a Logic "1" is applied to Q17, the 100 volt trip range is called; with the base of Q17 held at a Logic "0" and a Logic "1" applied to Q18, the 1000 volt trip range is in effect. Both relay drivers are PNP switches that are identical to the current limit and voltage trip switches.

3-117. The greater than 100 volt output detector of Q1, Q2 and Q3 samples the output and illuminates DS6 when the output voltage exceeds 100 volts. This provides a visual indication that the instrument has output voltages present that require caution in their application.

3-118. The configuration of Q15, Q16, and quad NOR gate IC1 forms an inhibit circuit which prevents the instrument from going into operate before passing through standby. Refer to Figure 3-8 for a simplified diagram of this circuit. The flip-flop is set initially to the proper state by the Logic "1" coming from S2 on the Switch Board (A3A2), when the standby position is selected. Should the instrument be in the operate mode when the power is turned on,

the flip-flop will be in the wrong state due to the Logic "0" from A3A2S2. A Logic "0" must be present at the output of the flip-flop (pin IC1 14) when the operate mode is selected; otherwise it is impossible to energize the instrument output's. If a Logic "1" (zero volts) is present at pin 14 when the operate mode is selected, Q15 and Q16 will turn on, holding the operate line down to nearly zero volts. The instrument must then be placed in the standby mode to set the flip-flop before the operate mode can be selected.

3-119. The indicator lamps provide visual indications of the instruments status while in local mode. The lamps and their function are:

DS1	Provide decimal point indication in association with the front panel Decade Dials.
DS2	
DS3	
DS4	
DS5	I LIMIT/V TRIP indicates limit or trip mode
DS6	OUTPUT > 100v
DS7	CONSTANT CURRENT
DS8	CONSTANT VOLTAGE
DS9	OPR operate mode
DS10	REM remote mode

3-120. DECADE SWITCH ASSEMBLY (A3A1). This assembly contains the seven decade switches used to select the desired output current or voltage while in local mode. Each switch is an eleven position switch; the highest order, S1, has positions ranging from 0 to 10, while the remaining switches S2 through S7 have a range of 0 to X. The "X" indicates a "carry one" function, so that an output voltage of, for example, 1100,0000 volts would be dialed as 10X0.0000.

3-121. On the schematic diagram the switches are shown for representation as 5 position switches, the positions being 8, 4, 2, 1, and 0 with numbers in parenthesis by the positions. The 8-4-2-1 corresponds to the BCD coding applied to the ladders. On S2 position 1, for example, the numbers 1, 3, 5, 7, 9, in parenthesis indicate that CR5 is connected to the wiper arm in the decade settings 1, 3, 5, 7, and 9.

3-122. The wiper arm of each switch is connected to -5 volts. The four outputs of each switch are connected to the appropriate relay driver in the ladder drive assembly.

3-123. SWITCH BOARD (A3A2) This assembly contains the front panel push button switches used to activate the various conditions in the instrument. The groups of

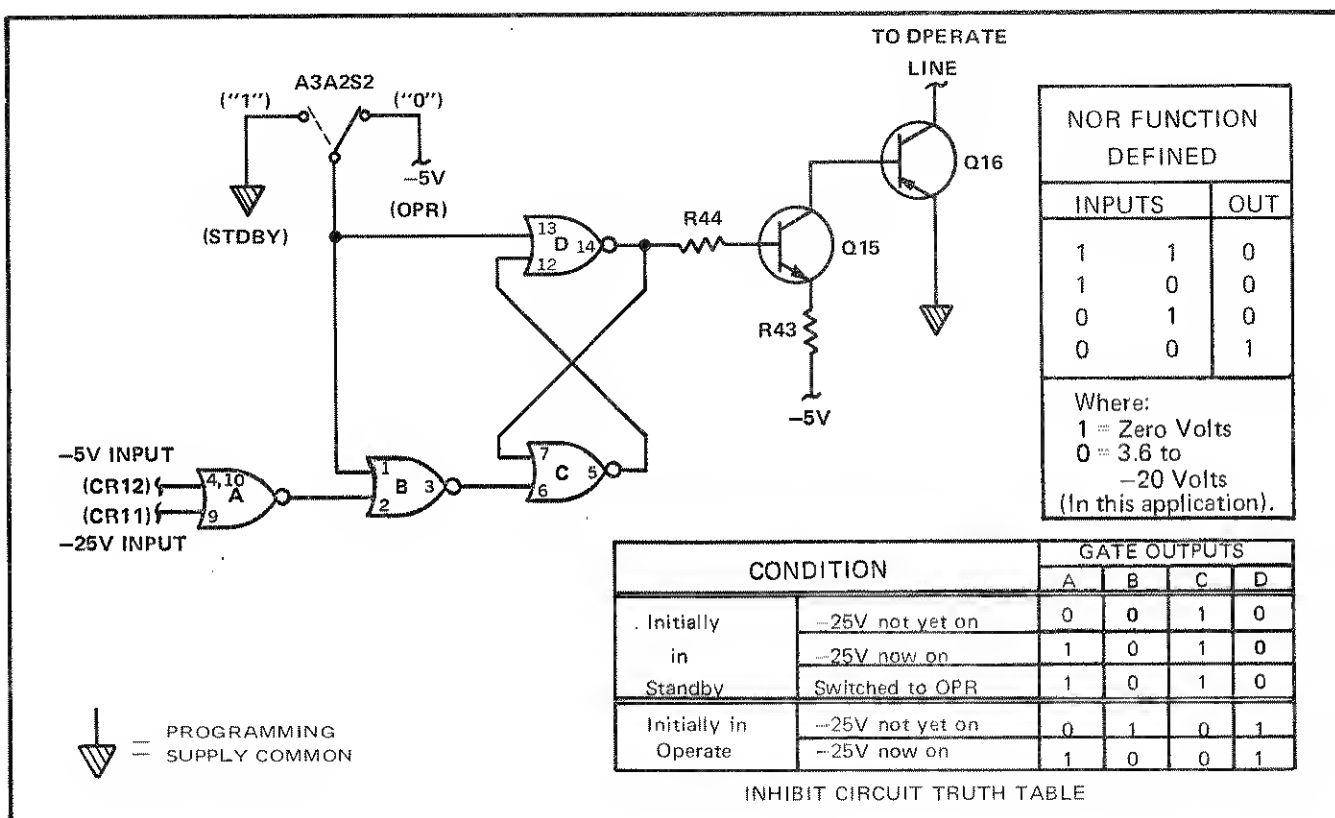


Figure 3-8. INHIBIT CIRCUIT

switches are mechanically linked so that if one switch in the group is depressed, the remaining non-appropriate switches are pushed into the non-depressed positions.

3-124. I LIMIT/V TRIP VERNIER (A3A3). Two variable resistors (R1 and R2) form this assembly. Both are front panel adjustments; R1 is the voltage limit trip, and R2 is the current limit vernier. Mechanically, the wiper arms form a sliding arrangement to allow selection of settings from LO to HI on the front panel.

### 3-125. Relay Board (A6)

3-126. Two relays are found on this assembly. K1, the operate relay, and K2, the Manual Crowbar relay.

### 3-127. Inner Chassis (A7)

3-128. Contained within the Inner Chassis assembly are three transformers arranged in a bracket. T1 is the primary power distribution transformer. T2 supplies ac power to the High Voltage Supply (A4A6) and obtains its input from the Pre-regulator (A5A2). T3 supplies power to the -25 and -5 volt Power Supply (A5A1).

### 3-129. Relay Summary

3-130. Figure 3-9 is provided to summarize the relays found in the 3330B. The decade ladder relays, current limit and voltage trip range ladder relays, and the time delay relay A5A1K1 are not included in the illustration.

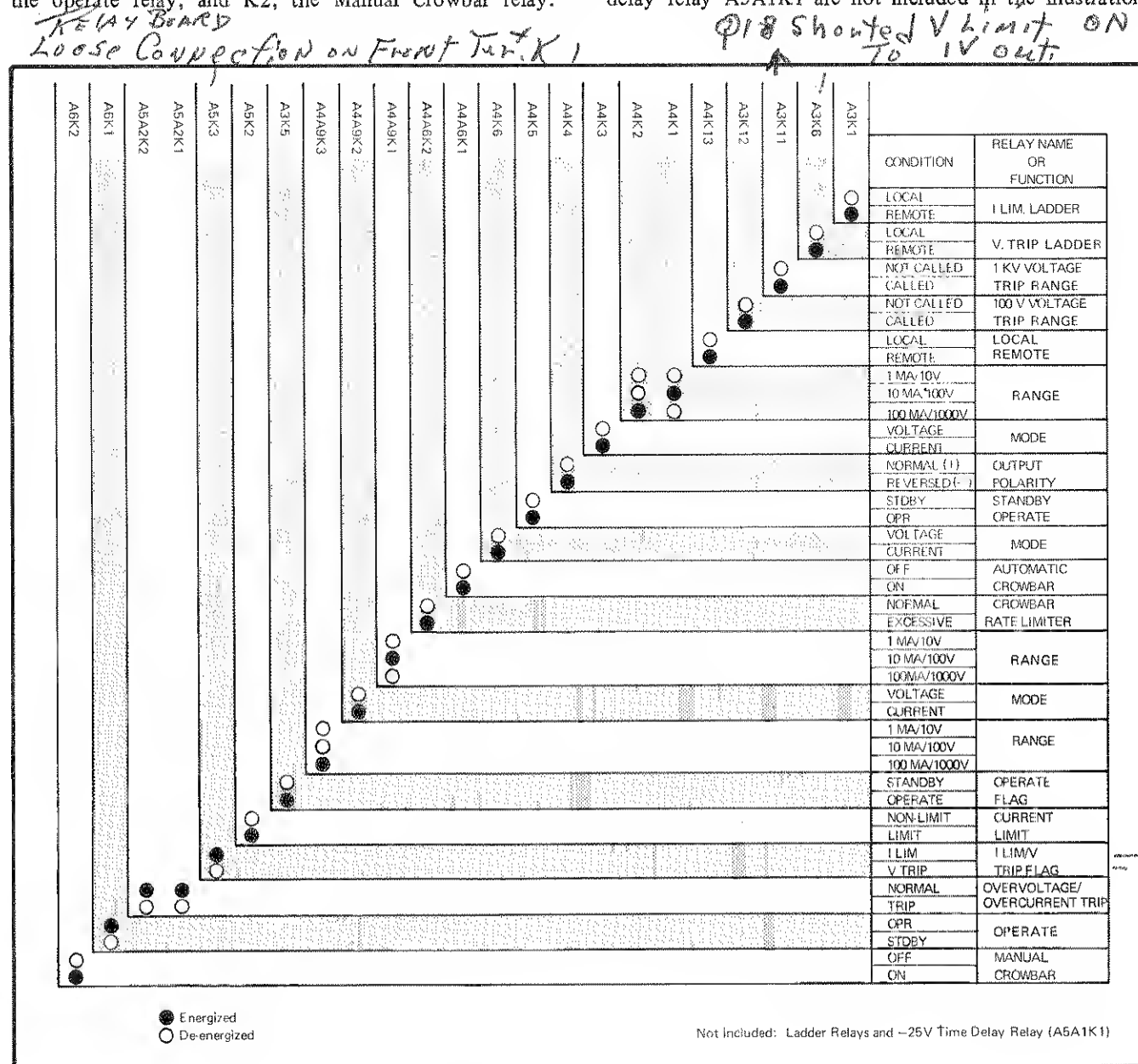


Figure 3-9. RELAY SUMMARY